National Science Foundation
Geosciences Directorate
Division of Ocean Sciences
Alexandria, Virginia

FINDING OF NO SIGNIFICANT IMPACT (FONSI) PURSUANT TO THE NATIONAL ENVIRONMENTAL POLICY ACT (NEPA) AND EXECUTIVE ORDER 12114 AND DECISION DOCUMENT (DD)

Marine Geophysical Survey of the Cascadia Subduction Zone in the Northeast Pacific Ocean, Late Spring/Summer 2021

Award: OCE 1827452
Principal Investigator/Institution: Suzanne Carbotte, Columbia University Lamont-Doherty Earth Observatory (LDEO)

Award: OCE 1827363
Principal Investigators/Institution: Gail Christeson, University of Texas Institute for Geophysics (UTIG)
Co-Principal Investigator/Institution: Shuo Shuo Han, UTIG

Award: OCE 1829113
Co-Principal Investigator/Institution: Juan Pablo Canales, Woods Hole Oceanographic Institution (WHOI)

Project Title: Collaborative Research: Illuminating the Cascadia plate boundary zone and accretionary wedge with a regional-scale ultra-long offset multi-channel seismic study

Award: OCE 1929545
Principal Investigator/Institution: Juan Pablo Canales, Woods Hole Oceanographic Institution (WHOI)
Co-Principal Investigator/Institution: Daniel Lizarralde, WHOI

Project Title: An Open-Access, Controlled-Source Seismic Dataset Across the Cascadia Accretionary Wedge From Multi-Scale Regional OBS and Focused Large-N Nodal Arrays

A Final Environmental Assessment (Final EA) was prepared for the above noted proposed research projects funded by the National Science Foundation (NSF) (Proposed Action). The Proposed Action would involve marine geophysical surveys (or "seismic surveys") to be conducted on board Research Vessel *Marcus G. Langseth* (R/V *Langseth*) and deployment of ocean bottom seismometers and nodes along the Cascadia margin during late spring/summer 2021. R/V *Langseth* is owned and operated by Columbia University's Lamont-Doherty Earth Observatory (LDEO). The Proposed Action would involve the Principal Investigators (PI) noted above and referred to herein as the "Proposing Institutions". The Proposed Action was originally proposed for late spring/summer 2020 but was deferred due to logistical issues associated with COVID-19 and unfinalized federal regulatory processes.

The Final EA entitled, "Final Environmental Assessment/Analysis of Marine Geophysical Surveys by R/V *Marcus G. Langseth* of the Cascadia Subduction Zone in the Northeast Pacific Ocean, 2021" (Report # FA0202-01) (Attachment 1), was prepared by LGL Limited environmental research associates (LGL) on behalf of NSF and analyzed the potential impacts on the human and natural environment associated with the Proposed Action pursuant to the National Environmental Policy Act (NEPA) and Executive Order 12114, "Environmental Effects Abroad of Major Federal Actions". The Final EA tiers to the *Programmatic Environmental Impact Statement/Overseas Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey* (June 2011) and the *Record of Decision* (June 2012) (jointly referred to herein as the PEIS). This Finding of No Significant Impact/Decision Document (FONSI/DD) also incorporates by reference the analyses and conclusions set forth in the Incidental Harassment Authorizations (IHAs) and the Biological Opinions (BiOps)/Incidental Take Statements (ITSs) issued by the U.S. National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) and U.S. Fish & Wildlife Service (FWS) for this Proposed Action. The conclusions from the Final EA, and other federal regulatory processes, were consistent with the conclusions of the PEIS and were used to inform the Division of Ocean Sciences (OCE) management of potential environmental impacts of the survey. OCE has reviewed and concurs with the Final EA findings. The Final EA is incorporated into this FONSI/DD by reference as if fully set forth herein.

Project Objectives and Context

The primary goals of the seismic surveys are to use two-dimensional (2-D) seismic surveying and Ocean Bottom Seismometers (OBS) and Ocean Bottom Nodes (OBN) to investigate the Cascadia Subduction Zone and provide data necessary to illuminate the depth, geometry, and physical properties of the seismogenic portion and updip extent of the megathrust zone between the subducting Juan de Fuca plate and the overlying accretionary wedge/North American plate. The data will yield new constraints on earthquake and tsunami potential in this heavily populated region of the Pacific Northwest. To achieve the project goals, the researchers propose to conduct 2-D reflection and refraction surveys using R/V *Langseth* along the Cascadia margin offshore Oregon, Washington, and Vancouver Island. The proposed surveys would occur within the Exclusive Economic Zones (EEZ) of Canada and the U.S., including within U.S. and Canadian Territorial Waters. The proposed surveys are illustrated with representative tracklines in the Final EA (Attachment 1, Figure 1). A complementary land-based research effort was also awarded by NSF. Although that project had independent utility and therefore underwent separate environmental review, it would capitalize on proposed R/V *Langseth* marine-based activities and would vastly expand the geophysical dataset available for analysis of the Cascadia margin. The collection of seismic data by R/V *Langseth* would also represent an essential step in the development of potential International Ocean Discovery Program (IODP) activities along the Cascadia margin.

Summary of Proposed Action and Alternatives

The procedures of the Proposed Action would be similar to those used during previous 2-D seismic surveys and would use conventional seismic methodology. The survey would involve one source vessel, R/V *Langseth*, which would tow a 36-airgun array with a discharge volume maximum of 6600 cubic inches (in^3) at a depth of 12 meters (m), and a shot interval of 37.5 m (approximately (~)17 seconds). The receiving system would consist of a 15-kilometer (km) long multichannel hydrophone streamer. OBSs and OBNs (OBS/Ns) would be deployed from R/V *Langseth* and/or R/V *Oceanus*; this OBS/N program would leverage the seismic surveys by R/V *Langseth*. As the airgun array is towed along the survey lines, a hydrophone streamer or the OBS/Ns would receive the returning acoustic signals; OBS/Ns would store the data internally for later analysis. In addition to the operations of the airgun array, a multibeam echosounder (MBES) and sub-bottom profiler (SBP) would be operated from R/V *Langseth* continuously throughout the cruise, but not during transit to or from the site. Approximately 6540 km of transect lines would be surveyed in the Northeast Pacific Ocean. Most of the survey (69%) would occur in deep water (>1000 m), 28% would occur in intermediate water (100–1000 m deep), and ~3% would take place in shallow water <100 m deep. Approximately 3.6% of the transect lines (234 km) would be undertaken in Canadian Territorial Waters, with most effort in intermediate waters.

The proposed surveys would be expected to last for ~40 days, including ~37 days of seismic operations, ~2 days of equipment deployment, and ~1 day of transit. During late spring/summer 2021, R/V *Langseth* would likely leave out of port in Newport, OR, and return to Seattle, WA. Some deviation in the length of the survey and ports of call may be required, depending on logistics and weather; however, seismic operations would only occur in the area noted and timeframe allowable under the IHA. The ensuing analysis (including take estimates) focuses on the time of the survey (late spring/summer); the best available species densities for that time of the year have been used.

Another alternative to conducting the Proposed Action would be the "No Action" alternative (i.e., the proposed research operations would not be conducted). The "No Action" alternative would result in no disturbance to marine species attributable to the Proposed Action, but geological data of considerable scientific value and relevance to increasing our understanding of the seismogenic zone along the Cascadia margin would not be collected. The purpose and need for the proposed activity would not be met through the "No Action" alternative.

Summary of environmental consequences

The Final EA includes analysis on the affected environment (Chapter III) and the potential effects of the Proposed Action on the environment (Chapter IV). Potential impacts of the Proposed Action on the environment would be primarily a result of the operation of the airgun array. The potential effects of sounds from airguns on marine species, including mammals and sea turtles of particular concern, are described in detail in Attachment 1 (Chapter IV and PEIS Chapters 3 & 4) and might include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects. It is unlikely that the Proposed Action would result in any cases of temporary or especially permanent hearing impairment, or any significant non-auditory physical or physiological effects. Some behavioral disturbance is expected if animals are in the general area during seismic operations, but this would be localized, short-term, and involve limited numbers of animals. The potential effects from the other proposed acoustic sources were also considered; however, they would not be likely to have a significant effect on the environment (Attachment 1, Chapter IV; and PEIS Chapter 3).

The Proposed Action includes an extensive monitoring and mitigation program to further minimize potential impacts on the environment. Mitigation efforts include pre-cruise planning activities and operational activities (Attachment 1, Chapters II and IV; and PEIS Section 2.4.1.1). Pre-cruise planning mitigation activities included consideration of energy source optimization/minimization; survey timing (i.e., environmental conditions: seasonal presence of animals and weather); and calculation of mitigation zones.

The operational mitigation program would further minimize potential impacts to marine species that may be present during the conduct of the proposed research to a level of insignificance. As detailed in Attachment 1 (Chapters II and IV), the IHA, ITS, and Letter of Concurrence issued by NMFS and USFWS, the Proposed Action would include operational monitoring and mitigation measures, such as, but not limited to: visual observations, acoustic monitoring, enforcement of exclusion and buffer zones, pre-clearance and ramp ups, shutdowns and power downs, monitoring and reporting. The fact that the airgun array, as a result of its design, directs the majority of the energy downward, and less energy laterally, would also be an inherent mitigation measure. The acoustic source would be shut down at any distance from the vessel during operations for observances of killer whales, North Pacific right whales, any large whale with a calf, and aggregation of large whales (defined as 6 or more). The shutdown requirement would be waived for small dolphins of the following genera: *Tursiops, Delphinus, Stenella, Lagenorhynchus, and Lissodelphis*.

The acoustic source would also be powered down (or, if necessary, shut down) in the event a sea turtle or an ESA-listed seabird were observed diving or foraging within the designated exclusion zone (EZ). Observers would also watch for any impacts the acoustic sources may have on fish. LDEO and its contractors are committed to applying these measures in order to minimize any effects on marine mammals, sea turtles, seabirds, and fish, and other potential environmental impacts. NMFS included vessel strike avoidance measures in the IHA; however, as noted in the Final EA, R/V *Langseth* (and other vessels in the U.S. Academic Research Fleet) have no history of marine mammal strikes. Although NSF calculated predicted distances to the Level A thresholds based on current NMFS Technical Acoustic Guidance[1], per the IHA, NMFS established a fixed operational 500 m exclusion zone and 1,000 m buffer zone for the survey; the IHA also requires a 1,500 m EZ for all beaked whales and dwarf and pygmy sperm whales. The predicted distances for the Level B zones are based on the 160 dB re 1 µPa SPL isopleth, per current NMFS policy for Level B harassment. Additional mitigation, monitoring and reporting requirements were identified through compliance with other regulatory processes, such as the Olympic Coast National Marine Sanctuary (OCNMS) permit and Canadian Fisheries Act. For example, in Canadian waters, the designated EZ for shut downs for sperm and beaked whales (any species) is 1500 m and for other marine mammal species and sea turtles is 1000 m. Mitigation, monitoring and reporting requirements were incorporated into the Final EA, the FONSI/DD, and/or the LDEO Science Support Plan; PSOs will take the lead in ensuring compliance with all monitoring and mitigation measures. LDEO has also prepared a communication plan to help keep stakeholders informed of operations; daily notifications will be sent to various groups when operating in particular areas, such as Tribal Usual and Accustomed (U&A) fishing areas.

With the planned monitoring and mitigation measures, unavoidable impacts to marine species that could be encountered would be expected to be minimal, and limited to short-term, localized changes in behavior and distribution near the seismic vessel. At most, effects on marine mammals may be interpreted as falling within the U.S. Marine Mammal Protection Act (MMPA) definition of Level B Harassment for those species managed by NMFS, however, NMFS also issued small numbers of Level A take for some marine mammal species for the remote possibility of low-level physiological effects from the Proposed Action. Although considered unlikely, any Level A harassment potentially incurred would be expected to be in the form of some smaller degree of permanent hearing loss due in part to the required monitoring measures for detecting marine mammals and required mitigation measures for power downs or shut downs of the airgun array if any animal is likely to enter the exclusion zones. Neither mortality nor complete deafness of marine mammals is expected to result from the surveys. No long-term or significant effects would be expected on individual marine mammals, sea turtles, seabirds, fish or the populations to which they belong or on their habitats. When operating within the Canadian EEZ, LDEO will follow the guidance provided by Fisheries and Oceans Canada (DFO) (Attachment 1, Appendix I), including the additional monitoring and mitigation measures, to avoid causing any harmful alteration, disruption, or destruction of fish (including marine mammal) habitat, or causing prohibited effects to aquatic species at risk.

The results of the cumulative impacts analysis in the PEIS indicated that there would not be any significant cumulative effects to marine resources from the proposed NSF-funded marine seismic research, including the combined use of airguns, MBES, SBP, and acoustic pingers. However, the PEIS also stated that cruise-specific cumulative effects analysis would be conducted, "allowing for the identification of other potential activities in the area of the proposed seismic survey that may result in cumulative impacts to environmental resources." The potential cumulative effects of the Proposed Action were evaluated in Section 4.1.6 of the Final EA. Due to the location of the Proposed Action, human activities in the area around the survey vessel

[1] 2018 Revision to: Technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (version 2.0). Underwater thresholds for onset of permanent and temporary threshold shifts. Office of Protected Resources, NMFS, Silver Spring, MD.

would be anticipated to include other research activities, possible Naval activities, vessel traffic, fisheries activities (e.g., commercial, subsistence, recreational), tourism, whaling and sealing. Because the proposed survey would occur mainly in water deeper than 60 m, any recreational diving is unlikely to be impacted. Fisheries activities within the region and potential impacts are described in further detail in the Final EA, Chapters III and IV. Fisheries activities would not be precluded in the survey area; however, a safe distance would need to be kept to avoid possible entanglement with the towed airgun array and OBS/N deployments. Conflicts would be avoided through Notice to Mariners and direct radio communications with fishers during the surveys. In addition, flyers and digital maps of the proposed tracklines and OBS/N deployments would be prepared and distributed to the fishing community to avoid conflicts, including in fishing gear stores in Oregon coastal towns. Survey start date and route plans would be shared with tribal points of contact and vessel operators would notify three days in advance of operating within tribal U&A fishing areas. Considering the limited time that the planned seismic survey would take place close to shore, where most subsistence fisheries activities would occur, and brief period of operations, the proposed project is not expected to have any significant impacts to the availability of subsistence fisheries. No fish kills or injuries were observed during any previous NSF-funded seismic survey activities. Given the brief duration of the proposed survey and the temporary nature of potential environmental impacts, no cumulative effects, or economic impacts to fisheries, would be anticipated. After review, the combined effects of the project and other potential human activities in the area are not anticipated to result in significant impacts on the environment.

The "No Action" alternative would remove the potential of the limited direct and indirect environmental consequences as described. However, it would preclude important scientific research from going forward that would contribute to our understanding of the Cascadia subduction zone, including earthquake and tsunami hazards. The proposed research would characterize subducting plate and accretionary wedge structure, and properties of the megathrust, along the Cascadia Subduction Zone. This regional characterization would be used to determine whether there are any systematic relationships among upper and lower plate properties, paleorupture segmentation, and along-margin variations in present-day coupling at Cascadia. The data would also be used to characterize down-dip variations along the megathrust that may be linked to transitions in fault properties, from the up-dip region near the deformation front, which is of most interest for tsunamigenesis, to near shore where the downdip transition in the locked zone may reside. Data collected would be made publicly available as a community data set (i.e., available for use by anyone). The "No Action" alternative would result in a lost opportunity to obtain important scientific data and knowledge relevant to the geosciences and to society in general. The collaboration, involving PIs and students, would be lost along with the collection of new data, future interpretation of these data and introduction of new results into the greater scientific community. Loss of NSF support often represents a significant negative impact to the academic infrastructure, including the professional and academic careers of the researchers, students, ship technicians and crew who are part of the U.S. Academic Research Fleet. The "No Action" alternative would not meet the purpose and need of the Proposed Action.

Public Engagement and Coordination with Other Agencies and Processes

NSF posted a Draft Environmental Assessment (Draft EA) on the NSF website for a 30-day public comment period from 7 February 2020 thru 7 March 2020 and sent notices to potential interested parties. Comments were received from three entities (Center for Biological Diversity, Oregon Department of Fish and Game, and a private citizen) and were addressed in the Final EA, Appendix E. In summary, concerns raised regarding the project were mainly focused on potential impacts to Sothern Resident Killer Whales (SRKW) and fisheries, including space/use conflicts.

NSF sent letters to tribal contacts to notify the tribes of the Proposed Action and NSF's related environmental compliance review, including the availability of the Draft EA, and also to provide an opportunity to consult. NSF discussed the project with a point of contact from the Quinault Nation. NSF understands the Makah Tribe sent a letter to NSF highlighting some points of concern about the project; however, the letter was unfortunately not received by NSF. NSF coordinated with the Makah Tribe Natural Resource Policy Analyst on the matter.

Based on comments received during the public comment period, consultations and federal regulatory processes, survey tracklines and OBS/N deployments were adjusted and additional operational restrictions required, including avoidance of anticipated high density areas of SRKW including critical habitat; eliminating operations in most waters <100 m; limiting seismic survey operations to daylight only and incorporating use of a support vessel with additional PSOs in water depths of 100-200 m in waters north of Tillamook Head, OR, and when operating in OCNMS. Proposed activities within the OCNMS would only cumulatively take ~1-2 days, and even less time would be spent within each tribal U&A fishing areas. R/V *Langseth* would move continuously during seismic survey operations. For those areas where there could be overlap with fishing vessels, the vessel operator would work to avoid space/use overlap through heightened and direct communication with fishermen in the area, as noted previously.

NSF coordinated with NMFS to complete the Final EA prior to issuance of an IHA and BiOp/ITS to accommodate NMFS' need to adopt NSF's Final EA as part of the NMFS NEPA process associated with issuing authorizations. NSF had enhanced coordination with NMFS and USFWS throughout the IHA and ESA consultation processes to facilitate this streamlined approach. As already highlighted, based on discussions with federal regulators during MMPA and Endangered Species Act (ESA) processes, refinements to the information in the Draft EA and planned operations were made. The new information included in the Final EA, however, did not alter the overall conclusions of the Draft EA and remained consistent with the PEIS.

Compliance with other federal statutes and regulatory processes are summarized below and in further detail in the Final EA, Section 4.1.8. In addition to these processes, efforts were made to coordinate with the U.S. Navy to avoid space-use conflicts and security matters. The U.S. Coast Guard will be notified about OBS/N placements. Due to their involvement with the Proposed Action, the U.S. Geological Survey agreed to be a Cooperating Agency.

(a) Endangered Species Act (ESA)
On 22 November 2019, NSF submitted a Letter of Concurrence request to USFWS that the proposed activity may affect but was not likely to adversely affect the ***endangered*** Hawaiian petrel and short-tailed albatross, and the ***threatened*** marbled murrelet. On 11 January 2020, USFWS provided a Letter of Concurrence (Attachment 1, Appendix F) that the proposed activity "may affect" but was not likely to "adversely affect" the Hawaiian petrel and short-tailed albatross, but did not concur for marbled murrelet, requesting additional information related to this species. In subsequent discussions with USFWS, they also identified that the Proposed Action could have potential effects on bull trout. On 12 April 2021, USFWS issued a BiOp on these species to NSF noting that the Proposed Action may affect, but is not likely to adversely affect the bull trout and its critical habitat, and that the Proposed Action is likely to adversely affect but is not likely to jeopardize the continued existence of the marbled murrelet (Attachment 1, Appendix F). Mitigation measures for ESA-listed seabirds would include power downs, and if necessary, shut downs for diving or foraging seabirds within the EZ.

On 8 November 2019, NSF submitted a formal ESA Section 7 consultation request, including the Draft EA, to NMFS for the proposed activity. NMFS conducted tribal outreach efforts consistent with *Secretarial Order (#3206): American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act*, to help inform their consultation on this action. Letters were sent to tribes with potential interest in the consultation. On 17 February 2021, NMFS held a webinar to discuss the project, including participation from representatives of tribes, NSF, and OCNMS. Per the request of the tribal representative attendees, an additional meeting focused on potential tribal fisheries interactions was held on 6 April 2021; NSF participated in the meeting.

On 3 March 2021, NOAA received a letter from the Makah Tribal Council outlining their general support of the project but making several requests, including that NSF (1) notify Makah Fisheries Management when the survey start date is finalized with route plans and anticipated dates of surveys within the Makah U&A fishing area, as well as three days in advance of reaching the Makah U&A fishing area; (2) adopt the enhanced mitigation measure to restrict seismic survey operations to daylight hours and include a second observer vessel within the Makah U&A fishing area regardless of depth to better ensure that ESA-listed marine mammals are identified and avoided; and (3) identify opportunities to monitor for acoustic impacts associated with the seismic surveys and make this data available to Makah Fisheries Management. NOAA, with input from NSF, provided a response to the Makah Tribe on 21 April 2021. The Makah Tribe also requested government to government consultation with NOAA; however, later communicated that a consultation meeting with NOAA Fisheries was not needed. NMFS issued a BiOp and ITS on 19 May 2021 (Attachment 2).

(b) Marine Mammal Protection Act (MMPA)
An IHA application was submitted on 8 November 2019 by LDEO on behalf of itself, NSF, and the researchers, to NMFS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals during the proposed seismic survey. On 7 April 2019, NMFS issued in the Federal Register a notice of intent to issue an IHA for the survey and a 30-day public comment period. Public comments were received from several entities during that process, including the Center for Biological Diversity, Ecojustice, and Deep Green Wilderness; NMFS considered the comments and will provide responses as required per the IHA process. NMFS issued an IHA for the proposed activity on 19 May 2021 (Attachment 3).

An IHA application was submitted on 20 December 2019 by LDEO on behalf of itself, NSF, and the researchers, to USFWS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals during the proposed seismic survey. NSF had additional dialog and correspondence with USFWS regarding the IHA application, including providing additional supplemental information. On 1 March 2021, USFWS issued in the Federal Register a notice of intent to issue an IHA for the survey and a 30-day public comment period (Attachment 1, Appendix D). Public comments were received from three entities during that process, including from the Marine Mammal Commission; USFWS considered the comments and will provide responses as required per the IHA process. USFWS issued an IHA for the proposed activity on 20 April 2021 (Attachment 1, Appendix D).

(c) Coastal Zone Management Act (CZMA)
On 20 December 2019, NSF submitted a determination that the Proposed Action was consistent to the maximum extent practicable with the enforceable policies of Oregon's Coastal Zone Management Program. On 4 March 2020, the Oregon Department of Land Conservation and Development confirmed presumed concurrence with the NSF determination that the proposed activity is consistent to the maximum extent practicable with the enforceable policies of Oregon's Coastal Zone Management Program (CZMP) (Attachment 1, Appendix G). During this process, some concerns were raised related to potential space-use conflicts with fishers; however, as noted in the Draft EA Section 4.1.2.4 and 4.1.5, NSF anticipates limited space-use conflict with fishers. Enhanced outreach efforts and coordination with members of the fishing industry have occurred to help further reduce any potential space use conflicts.

On 8 January 2020, NSF submitted a determination that the Proposed Action was consistent to the maximum extent practicable with the enforceable policies of Washington's CZMP. On 23 March 2020, the State of Washington Department of Ecology, pursuant to the Coastal Zone Management Act of 1972 as amended, concurred with NSF's determination that the proposed work is consistent with Washington's

CZMP, and that NSF demonstrated that the Proposed Action is consistent with the CZMP's enforceable policies found in Washington's Ocean Resource's Management Act and the Ocean Management Guidelines (Attachment 1, Appendix G).

(d) National Marine Sanctuary Act (NMSA)/Olympic Coast National Marine Sanctuary (OCNMS)
On 19 December 2019, LDEO submitted a permit application to OCNMS for activities that would occur within the Sanctuary. A Sanctuary Resource Statement (SRS) was submitted to the Office of National Marine Sanctuaries (ONMS) on 16 March 2020 by NSF and NMFS. After the survey originally scheduled for 2020 was deferred, the permit was updated for the spring/summer 2021 timeframe and resubmitted to OCNMS on 15 June 2020. As part of the permit process, OCNMS also sought input on the application from the Hoh, Makah, Quileute tribes, and Quinault Nation. On 19 May 2020, the Quileute Tribe submitted comments on the permit application to OCNMS. In particular, the Tribe stated that they did not support the abandonment of any equipment in the marine environment, including the OBS anchors. No OBSs or anchors would be deployed within the Quileute Tribal U&A fishing area. Based on this input, however, NSF modified the originally proposed plan to use within the Sanctuary steel anchors for the OBSs to concrete anchors, which while still cannot be retrieved, should degrade faster and mainly to sand.

After requesting additional information in January 2021, a revised SRS was submitted on 22 January 2021. ONMS found, on 27 January 2021, that the SRS was sufficient to make an injury determination. In their final determination dated 12 March 2021, ONMS made two alternative recommendations to further minimize injury and protect sanctuary resources: (1) limit operations in OCNMS to daylight hours only regardless of depth, and (2) use of the secondary support vessel aiding in marine mammal observations throughout the entire sanctuary (Attachment 1, Appendix H). On 19 March 2021, NSF notified ONMS/OCNMS the alternative recommendations were accepted and understood no further consultation with ONMS/OCNMS was necessary prior to conducting the Proposed Action. OCNMS issued the permit on 2 April 2021 (Attachment 1, Appendix H).

(e) Essential Fish Habitat (EFH)
EFH and Habit Areas or Particular Concern (HAPCs) were identified to occur within the proposed survey area. Although NSF anticipated no significant impacts to EFH and HAPC, as the Proposed Action may affect EFH and HAPC, in accordance with the Magnuson-Stevens Fishery Conservation and Management Act, NSF requested consultation with NMFS on14 November 2019. In discussions with NMFS, it was determined to incorporate the EFH process into the ESA consultation. On 19 May 2021, NMFS issued its BiOp which included information and determination on EFH (Attachment 2).

(f) Canadian Department of Fisheries and Oceans (DFO)
An application for a Species at Risk permit application per the Species at Risk Act (SARA) was submitted on 19 December 2019. After discussion with DFO staff, the Species at Risk application was revised and resubmitted along with a Canadian Fisheries Act Request for Review on 18 December 2020. After consultation with DFO, all proposed transect lines and their associated 160-dB ensonified area were moved out of Canadian critical habitat for SRKW. On 6 April 2021, DFO issued a Letter of Advice with measures to follow to avoid causing the death of fish (including marine mammals) and/or harmful alteration, disruption, or destruction of fish habitat, or causing prohibited effects to SARA species, any part of their critical habitat or the residences of their individuals (Attachment 1, Appendix I).

Conclusion and Decision
NSF has reviewed and concurs with the conclusions of the Final EA (Attachment 1) that implementation of the Proposed Action will not have a significant impact on the environment. Consequently, implementation of the Proposed Action will not have a significant direct, indirect or cumulative impact on the environment within the meaning of NEPA or EO 12114. Because no significant environmental impacts

will result from implementing the Proposed Action, an environmental impact statement is not required and will not be prepared. Therefore, no further study under NEPA or EO 12114 is required.

As described above, NSF's compliance with the ESA, MMPA, CZMA, NMSA/OCNMS, EFH, and the Canadian Fisheries Act is completed.

In sum, after full consideration of the Final EA, the PEIS, the IHAs and ITSs issued by NMFS and USFWS, the Letter of Concurrence from USFWS, the CZMA and EFH determinations, NMSA SRS determination and OCNMS permit issued, DFO Letter of Advice, and the entire environmental compliance record, NSF concludes that implementation of the Proposed Action will not result in significant impacts. Accordingly, on behalf of NSF, I authorize the issuance of a Finding of No Significant Impact for the Proposed Action, the marine seismic survey proposed to be conducted on board Research Vessel *Marcus G. Langseth* and OBS/N deployments along the Cascadia subduction zone during the effective time period of the IHAs, and hereby approve the Proposed Action to commence.

Bauke Houtman 20 May 2021

Bauke (Bob) Houtman Date
Integrative Programs Section Head
Division of Ocean Sciences

Attachment 1: Final Environmental Assessment/Analysis of Marine Geophysical Surveys by R/V *Marcus G. Langseth* of the Cascadia Subduction Zone in the Northeast Pacific Ocean, 2021
Attachment 2: NMSF Biological Opinion/Incidental Take Statement
Attachment 3: NMFS Incidental Harassment Authorization

Attachment 1

Final Environmental Assessment/Analysis of Marine Geophysical Surveys by R/V *Marcus G. Langseth* of the Cascadia Subduction Zone in the Northeast Pacific Ocean, 2021

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ABSTRACT

Researchers from Lamont-Doherty Earth Observatory (L-DEO) of Columbia University, Woods Hole Oceanographic Institution (WHOI), and the University of Texas at Austin Institute of Geophysics (UTIG), with funding from the U.S. National Science Foundation (NSF), and in collaboration with researchers from Dalhousie University and Simon Fraser University (SFU), propose to conduct high-energy seismic surveys from the Research Vessel (R/V) *Marcus G. Langseth* (*Langseth*) in combination with Ocean Bottom Seismometers and Nodes at the Cascadia Subduction Zone in the Northeast Pacific Ocean during late spring/summer 2021. R/V *Langseth* is owned by Columbia University and operated by L-DEO. The proposed two-dimensional (2-D) seismic surveys would occur within Exclusive Economic Zones (EEZ) of Canada and the U.S., including U.S. and Canadian Territorial Waters. The surveys would use a 36-airgun towed array with a total discharge volume of ~6600 in^3 and would occur in water depths ranging from 60–4400 m.

NSF, as the research funding and action agency, has a mission to "promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…". The proposed seismic surveys would collect data in support of two research proposals that have been reviewed under the NSF merit review process and identified as an NSF program priority. They would serve to investigate the Cascadia Subduction Zone and provide data necessary to illuminate the depth, geometry, and physical properties of the seismogenic portion and updip extent of the megathrust zone between the subducting Juan de Fuca plate and the overlying accretionary wedge/North American plate providing essential constraints for earthquake and tsunami hazard assessment in this heavily populated region of the Pacific Northwest. The portion of the megathrust targeted for this survey is the source region for great earthquakes that occurred at Cascadia in pre-historical times, comparable in size to the Tohoku M9 earthquake in 2011; an earthquake of similar size is possible at Cascadia within the next century.

This Final Environmental Assessment/Analysis (EA) addresses NSF's requirements under the National Environmental Policy Act (NEPA) for the proposed NSF federal action within the U.S. EEZ and Executive Order 12114, "Environmental Effects Abroad of Major Federal Actions", for the proposed NSF federal action within the Canadian EEZ. Due to their involvement with the Proposed Action, the U.S. Geological Survey (USGS) has agreed to be a Cooperating Agency. As operator of R/V *Langseth*, L-DEO, on behalf of itself, NSF, WHOI, and UTIG, requested an Incidental Harassment Authorization (IHA) from the U.S. National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) to authorize the incidental (i.e., not intentional) harassment of small numbers of marine mammals should this occur during the seismic surveys. The analysis in this document supports the IHA application process and provides additional information on marine species that are not addressed by the IHA application, including sea turtles, seabirds, fish, and invertebrates that are listed under the U.S. Endangered Species Act (ESA), including candidate species. As analysis on endangered and threatened species was included, the Draft EA was used to support ESA Section 7 consultations with NMFS and USFWS. Alternatives addressed in this EA consist of the Proposed Action with issuance of an associated IHA and the No Action alternative, with no IHA and no seismic surveys. This document tiers to the Programmatic Environmental Impact Statement/Overseas Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey (June 2011) and Record of Decision (June 2012), referred to herein as PEIS. This document also tiers to the Environmental Assessment of Marine Geophysical Surveys by the R/V *Marcus G. Langseth* in the Northeastern Pacific Ocean, June–July 2012 and issued Finding of No Significant Impact for similar seismic surveys conducted in 2012 in, or near, the proposed survey area.

Numerous species of marine mammals inhabit the proposed project area in the northeastern Pacific Ocean. Under the U.S. ESA, several of these species are listed as ***endangered***, including the North Pacific right, humpback (Central America Distinct Population Segment or DPS), sei, fin, blue, sperm, and Southern Resident DPS of killer whales. It is unlikely that a gray whale from the ***endangered*** Western North Pacific DPS would occur in the project area at the time of the surveys. In addition, the ***threatened*** Mexico DPS of the humpback whale and the ***threatened*** Guadalupe fur seal could occur in the proposed project area. The North Pacific right whale, the Pacific populations of sei and blue whales, and Southern Resident killer whales are also listed as *endangered* under Canada's *Species at Risk Act* (SARA); the Pacific population of fin whale, and all other populations of killer whales in the Pacific Ocean are listed as *threatened*. The northern sea otter is the one marine mammal species mentioned in this document that, in the U.S., is managed by the USFWS; all others are managed by NMFS. After discussions with USFWS, the original survey design was adjusted to minimize take of sea otters. The sea otter is considered *special concern* under SARA.

ESA-listed sea turtle species that could occur in the project area include the ***endangered*** leatherback turtle and ***threatened*** East Pacific DPS of the green turtle; the Pacific population of leatherback turtle is also listed as *endangered* under SARA, but the green turtle is not listed. ESA-listed seabirds that could be encountered in the area include the ***endangered*** short-tailed albatross (also *endangered* under SARA) and Hawaiian petrel, and the ***threatened*** marbled murrelet (also *threatened* under SARA); the Hawaiian petrel is not listed under SARA.

Several ESA-listed fish species occur in the area, including the ***endangered*** Puget Sound/Georgia Basin DPS of bocaccio; the ***threatened*** Pacific eulachon (Southern DPS), green sturgeon (Southern DPS), yelloweye rockfish, and several DPSs of steelhead trout; and various ***endangered*** and ***threatened*** evolutionary significant units (ESUs) of chinook, chum, coho, and sockeye salmon. In addition, the ***threatened*** bull trout could also occur in shallow water along the coast. In Canada, the South Coast British Columbia population of bull trout is considered *special concern*. The basking shark and northern abalone are listed as *endangered* under SARA

Potential impacts of the proposed seismic surveys on the environment would be primarily a result of the operation of the airgun array. A multibeam echosounder and sub-bottom profiler would also be operated during the surveys. Impacts from the Proposed Action would be associated with increased underwater anthropogenic sounds, which could result in avoidance behavior by marine mammals, sea turtles, seabirds, and fish, and other forms of disturbance. An integral part of the planned surveys is a monitoring and mitigation program designed to minimize potential impacts of the proposed activities on marine animals present during the proposed surveys, and to document, as much as possible, the nature and extent of any effects. Injurious impacts to marine mammals, sea turtles, and seabirds have not been proven to occur near airgun arrays or the other types of sound sources to be used. However, a precautionary approach would still be taken; the planned monitoring and mitigation measures would reduce the possibility of any effects.

Protection measures designed to mitigate the potential environmental impacts to marine mammals, sea turtles, and seabirds would include the following: ramp ups; typically two (but a minimum of one) dedicated observers maintaining a visual watch during all daytime airgun operations; two observers before and during ramp ups during the day; start-ups during poor visibility or at night if the exclusion zone (EZ) has been acoustically monitored (e.g., passive acoustic monitoring (PAM)) for at least 30 min with no detections; PAM via towed hydrophones during both day and night to complement visual monitoring; shut downs when marine mammals are detected in or about to enter the designated EZ. The acoustic source would also be powered down (or if necessary, shut down) in the event a sea turtle or an ESA-listed seabird

would be observed diving or foraging within the designated EZ. Observers would also watch for any impacts the acoustic sources may have on fish. L-DEO and its contractors are committed to applying these measures in order to minimize effects on marine mammals, sea turtles, seabirds, and fish, and other potential environmental impacts. Ultimately, survey operations would be conducted in accordance with all applicable international, U.S. federal, and state regulations, including IHA and Incidental Take Statement (ITS) requirements.

With the planned monitoring and mitigation measures, unavoidable impacts to each species of marine mammal and sea turtle that could be encountered would be expected to be limited to short-term, localized changes in behavior and distribution near the seismic vessel. At most, effects on marine mammals would be anticipated as falling within the Marine Mammal Protection Act (MMPA) definition of "Level B Harassment" for those species managed by NMFS. No long-term or significant effects would be expected on individual marine mammals, sea turtles, seabirds, fish, the populations to which they belong, or their habitats. Although Level A takes are very unlikely, NSF followed the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2016a, 2018a), resulting in the estimation of Level A takes for some marine mammal species. No significant impacts would be expected on the populations of those species for which a Level A take is permitted.

LIST OF ACRONYMS

~	approximately
2-D	two-dimensional
ADCP	Acoustic Doppler Current Profiler
AEP	Auditory Evoked Potential
AIS	Automatic Identification System
AMVER	Automated Mutual-Assistance Vessel Rescue
B.C.	British Columbia, Canada
BIA	Biologically Important Area
CA	California
CBD	Convention on Biological Diversity
CCE	California Current Ecosystem
CITES	Convention on International Trade in Endangered Species
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DAA	Detailed Analysis Area
dB	decibel
DFO	(Canada) Department of Fisheries and Oceans
DPS	Distinct Population Segment
EA	Environmental Assessment/Analysis
EBSA	Ecologically or Biologically Significant Marine Areas
EFH	Essential Fish Habitat
EHV	Endeavour Hydrothermal Vents
EIS	Environmental Impact Statement
EO	Executive Order
ESA	(U.S.) Endangered Species Act
ETOMO	Endeavour Tomography
ETP	Eastern Tropical Pacific
EZ	Exclusion Zone
FM	Frequency Modulated
FONSI	Finding of no significant impact
GIS	Geographic Information System
GoM	Gulf of Mexico
h	hour
HAPC	Habitat Area of Particular Concern
hp	horsepower
Hz	Hertz
IHA	Incidental Harassment Authorization (under MMPA)
in	inch
ITS	Incidental Take Statement
IUCN	International Union for the Conservation of Nature
IWC	International Whaling Commission
kHz	kilohertz
km	kilometer
kt	knot
L-DEO	Lamont-Doherty Earth Observatory
LFA	Low-frequency Active (sonar)
LME	Large Marine Ecosystem
m	meter
MBES	Multibeam Echosounder
MCS	Multi-Channel Seismic
MFA	Mid-frequency Active (sonar)
min	minute
MMPA	(U.S.) Marine Mammal Protection Act

MPA	Marine Protected Area
ms	millisecond
NMFS	(U.S.) National Marine Fisheries Service
nmi	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NPC	The North Pacific Current
NRC	(U.S.) National Research Council
NSF	National Science Foundation
OBN	Ocean Bottom Node
OBS	Ocean Bottom Seismometer
OBSIC	Ocean Bottom Seismometer Instrument Center
ODFW	Oregon Department of Fish and Wildlife
OEIS	Overseas Environmental Impact Statement
OFCC	Oregon Fishermen's Cable Committee
OOI	Ocean Observatories Initiative
p or pk	peak
PDO	Pacific Decadal Oscillation
PEIS	Programmatic Environmental Impact Statement
PI	Principal Investigator
PTS	Permanent Threshold Shift
PSO	Protected Species Observer
QAA	Qualitative Analysis Area
rms	root-mean-square
ROV	remotely operated vehicle
R/V	research vessel
s	second
SAFE	Scientists and Fishermen Exchange (Program)
SARA	(Canada) *Species at Risk Act*
SBP	Sub-bottom Profiler
SEL	Sound Exposure Level (a measure of acoustic energy)
SFU	Simon Fraser University
SIO	Scripps Institution of Oceanography
SPL	Sound Pressure Level
SOSUS	(U.S. Navy) Sound Surveillance System
SWFSC	Southwest Fisheries Science Center
t	tonnes
TTS	Temporary Threshold Shift
U.K.	United Kingdom
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
U.S.	United States of America
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
UTIG	University of Texas at Austin, Institute of Geophysics
μPa	microPascal
vs.	versus
WCMC	World Conservation Monitoring Centre
WHOI	Woods Hole Oceanographic Institution
y	year

I Purpose and Need

This Final Environmental Assessment/Analysis (EA) addresses NSF's requirements under the National Environmental Policy Act (NEPA) and Executive Order 12114, "Environmental Effects Abroad of Major Federal Actions". The Final EA tiers to the Final Programmatic Environmental Impact Statement (PEIS)/Overseas Environmental Impact Statement (OEIS) for Marine Seismic Research funded by the National Science Foundation or Conducted by the U.S. Geological Survey (NSF and USGS 2011) and Record of Decision (NSF 2012), referred to herein as the PEIS. This document also tiers to the EA of Marine Geophysical Surveys by R/V *Marcus G. Langseth* in the Northeastern Pacific Ocean, June–July 2012 and associated Finding of No Significant Impact (FONSI) for similar seismic surveys conducted in 2012 in, or near, the proposed survey area.[1] The purpose of this Final EA is to provide the information needed to assess the potential environmental impacts associated with the Proposed Action, including the use of an airgun array during the proposed seismic surveys. Due to their involvement with the Proposed Action, the U.S. Geological Survey (USGS) has agreed to be a Cooperating Agency.

The Final EA provides details of the Proposed Action at the site-specific level and addresses potential impacts of the proposed seismic surveys on marine mammals, sea turtles, seabirds, fish, and invertebrates. The Draft EA was used in support of other regulatory processes, including an application for an Incidental Harassment Authorization (IHA) and Section 7 consultations under the *Endangered Species Act* (ESA) with the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS). The IHA would allow the non-intentional, non-injurious "take by harassment" of small numbers of marine mammals[2] during the proposed seismic surveys by Columbia University's Lamont-Doherty Earth Observatory (L-DEO) in the Northeast Pacific Ocean during late spring/summer 2021. Following the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2016a, 2018a), small numbers of Level A takes have been requested for the remote possibility of low-level physiological effects; however, because of the characteristics of the Proposed Action and proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, Level A takes are considered highly unlikely.

The Final EA addresses: (1) comments received during federal regulatory consultations, public comment periods, and tribal coordination, including those received during the NSF NEPA, NMFS/FWS IHA, NMFS/USFWS ESA, and Olympic Coast National Marine Sanctuary (OCNMS) processes, (2) a schedule change from late spring 2020 to late spring/summer 2021 due to COVID-19 impacts, and (3) a change in the mitigation zones from the Draft EA, based on both modeling for the Level A and Level B thresholds and using empirical measurements from Crone et al. (2014) from the Cascadia Margin, that were then used to revise the take estimates.

1.1 Mission of NSF

The National Science Foundation (NSF) was established by Congress with the National Science Foundation Act of 1950 (Public Law 810507, as amended) and is the only federal agency dedicated to the

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[1] EA and FONSI available on the NSF website (https://www.nsf.gov/geo/oce/envcomp/index.jsp).

[2] To be eligible for an IHA under the MMPA, the proposed "taking" (with mitigation measures in place) must not cause serious physical injury or death of marine mammals, must have negligible impacts on the species and stocks, must "take" no more than small numbers of those species or stocks, and must not have an unmitigable adverse impact on the availability of the species or stocks for legitimate subsistence uses.

support of fundamental research and education in all scientific and engineering disciplines. Further details on the mission of NSF are described in § 1.2 of the PEIS.

1.2 Purpose of and Need for the Proposed Action

As noted in the PEIS, § 1.3, NSF has a continuing need to fund seismic surveys that enable scientists to collect data essential to understanding the complex Earth processes beneath the ocean floor. The purpose of the proposed study is to use two-dimensional (2-D) seismic surveying and Ocean Bottom Seismometers (OBS) and Ocean Bottom Nodes (OBN) to investigate the Cascadia Subduction Zone and provide data necessary to illuminate the depth, geometry, and physical properties of the seismogenic portion and updip extent of the megathrust zone between the subducting Juan de Fuca plate and the overlying accretionary wedge/North American plate, providing new constraints on earthquake and tsunami potential in this heavily populated region of the Pacific Northwest. The proposed activities would collect data in support of two research proposals that were reviewed through the NSF merit review process and were identified as NSF program priorities to meet the agency's critical need to foster an understanding of Earth processes.

1.3 Background of NSF-funded Marine Seismic Research

The background of NSF-funded marine seismic research is described in § 1.5 of the PEIS.

1.4 Regulatory Setting

The regulatory setting of this EA is described in § 1.8 of the PEIS, including the

- Executive Order 12114;
- National Environmental Protection Act (NEPA) of 1969 (42 United States Code [USC] §4321 *et seq.*); the Council on Environmental Quality (CEQ) Regulations for Implementing the Procedural Provisions of NEPA (Title 40 Code of Federal Regulations [CFR] §§ 1500-1508 (1978, as amended in 1986 and 2005))[3]; NSF procedures for implementing NEPA and CEQ regulations (45 CFR 640);
- Marine Mammal Protection Act (MMPA) of 1972 (16 USC 1631 *et seq*.);
- Endangered Species Act (ESA) of 1973 (16 USC ch. 35 §1531 *et seq.*);
- National Historic Preservation Act (NHPA) (Public Law 89-665; 54 USC 300101 *et seq.*);
- Coastal Zone Management Act (CZMA) of 1972 (16 USC §§1451 *et seq.*);
- National Marine Sanctuaries Act (16 USC §1431 *et seq.*); and
- Magnuson-Stevens Fishery Conservation and Management Act - Essential Fish Habitat (EFH) (Public Law 94-265; 16 USC ch. 38 §1801 *et seq*.).

II ALTERNATIVES INCLUDING PROPOSED ACTION

In this Final EA, two alternatives are evaluated: (1) the proposed seismic surveys and associated issuance of an associated IHA and (2) No Action alternative. Additionally, two alternatives were considered but were eliminated from further analysis. A summary of the Proposed Action, the alternative, and alternatives eliminated from further analysis is provided at the end of this section.

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[3] This EA is being prepared using the 1978 CEQ NEPA Regulations. NEPA reviews initiated prior to the effective date of the 2020 CEQ NEPA regulations may be conducted using the 1978 version of the regulations. The effective date of the 2020 CEQ NEPA Regulations was September 14, 2020. This NEPA review began prior to this date (e.g., the Draft EA was posted for public comment on the NSF website 7 February 2020), and the agency has decided to proceed under the 1978 regulations.

2.1 Proposed Action

The Final EA includes analysis for two separate proposals received by NSF; however, due to their linked and dependent nature, they are considered the Proposed Action and are jointly analyzed herein. The Proposed Action, including project objectives and context, activities, and monitoring/mitigation measures for the proposed seismic surveys and use of OBSs and OBNs, is described in the following subsections.

2.1.1 Project Objectives and Context

Researchers from L-DEO, Woods Hole Oceanographic Institution (WHOI), and the University of Texas at Austin Institute of Geophysics (UTIG), have proposed to conduct seismic surveys using R/V *Langseth* in the Northeast Pacific Ocean (Fig. 1). Although not funded through NSF, collaborators from the USGS, Drs. M. Nedimovic (Dalhousie University), and A. Calvert (Simon Fraser University; SFU) would work with the PIs to achieve the research goals, providing assistance, such as through logistical support, and data acquisition and exchange.

OBSs and OBNs would leverage the seismic surveys by R/V *Langseth*. A complementary land-based research effort is also under consideration for NSF funding. Although the project has independent utility and therefore would undergo separate environmental review, the project would capitalize on proposed R/V *Langseth* marine-based activities and would vastly expand the geophysical dataset available for analysis for the Cascadia region. In addition, the proposed deep-penetration survey would complement the shallow-imaging study by the USGS that is planned for the region as part of their multi-year hazard assessment study. The collection of seismic data by R/V *Langseth* would also represent an essential step in the development of International Ocean Discovery Program (IODP) activities along the Cascadia margin. The IODP project, which is not part of the Proposed Action, has been reviewed in a pre-proposal by the IODP Science Evaluation Panel. To complete the full proposal and subsequently execute its science plan, seismic data must be collected to identify drilling targets and to evaluate their suitability from both scientific and safety perspectives. The following information provides an overview of the research project objectives associated with the surveys.

At the Cascadia Subduction Zone, the slow ongoing descent of the Juan de Fuca plate beneath the northwestern coast of North America has generated large earthquakes and associated tsunamis in the past. Geologic records suggest that some sections of the subduction zone fault or "megathrust", which extends ~35–90 mi. seaward from the coasts of northern California all the way to southern British Columbia (B.C.), slipped less than other sections during the last earthquake (1700 AD), and that in some prior large earthquakes, only parts of the subduction zone ruptured. The last earthquake is estimated to have been of magnitude 9, similar to that of the Tohoku earthquake in Japan in 2011; an earthquake of similar size is possible at Cascadia within the next century. Whether current inferences of along-margin variations in fault slip during the last earthquake may persist in future ruptures has important implications for quantifying earthquake and tsunami hazards for the population centers of the Pacific Northwest. Geologic structure such as seamounts and other topographic features in the descending Juan de Fuca plate, the structure and properties of the thick folded and faulted package of sediments that forms above the subduction zone fault, or the properties of megathrust fault rocks, could contribute to these along-margin variations. While at most of the World's subduction zones there is abundant present-day seismicity along the megathrust which can be used to constrain first-order properties of the subduction fault including its depth and geometry, the Cascadia Subduction Zone is "eerily" quiet with little seismicity recorded from much of the megathrust. With the paucity of instrumentally-recorded seismicity and the lack of offshore geodetic constraints on the distribution of interseismic locking, little is known of the properties of the subduction zone fault interface

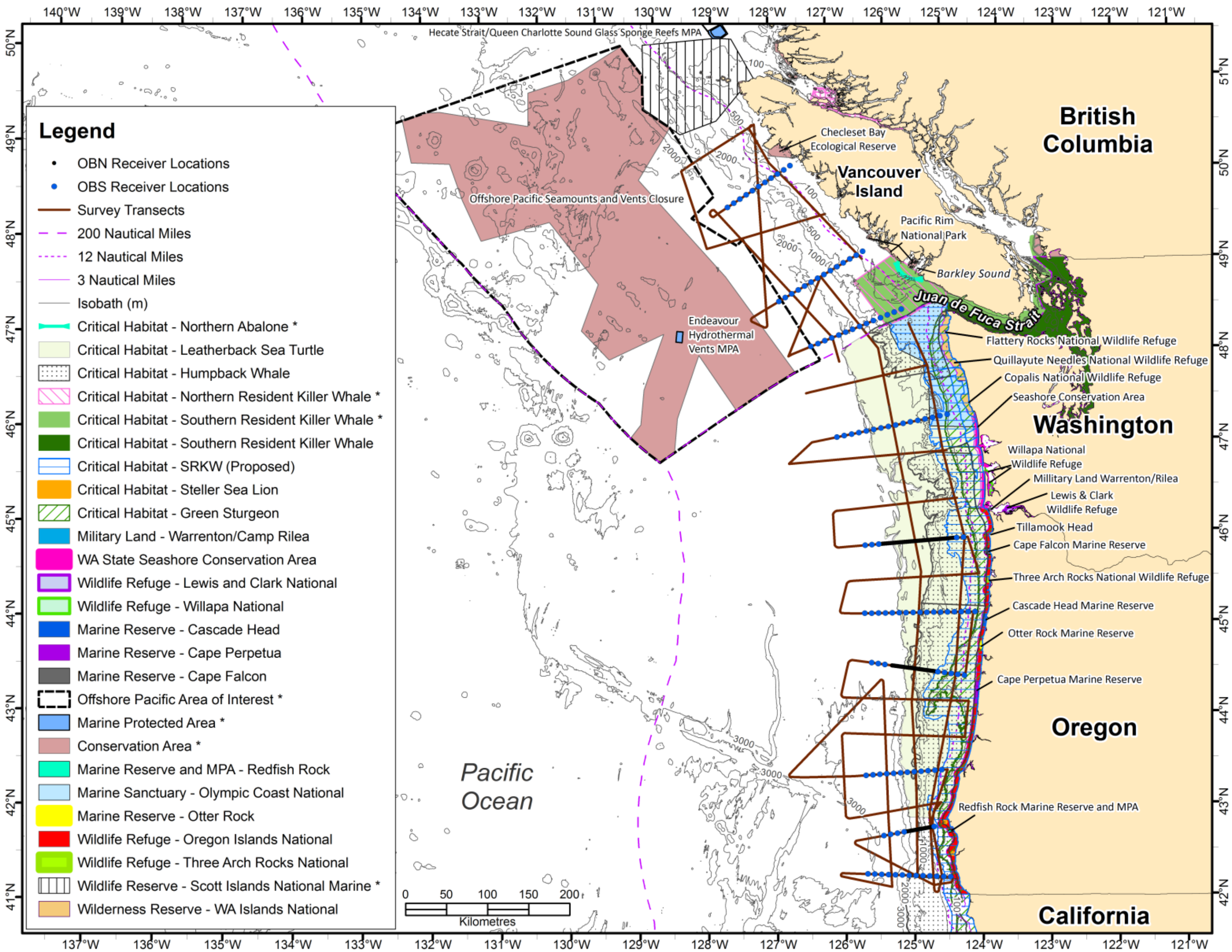

FIGURE 1. Location of the proposed seismic surveys in the Northeast Pacific Ocean and conservation areas near the proposed survey location. Canadian conservation areas and critical habitat are denoted by *. WA = Washington; SRKW – Southern Resident Killer Whale.

within the mega-thrust earthquake zone and how they vary along and across strike. The current observations allow for a wide range of possible future earthquake scenarios.

The acquired data would be designed to characterize: 1) the deformation and topography of the incoming plate; 2) the depth, topography, and reflectivity of the megathrust; 3) sediment properties and amount of sediment subduction; and 4) the structure and evolution of the accretionary wedge, including geometry and reflectivity of fault networks, and how these properties vary along strike, spanning the full length of the margin and down dip across what may be the full width of the seismogenic zone at Cascadia. The data would be processed to pre-stack depth migration using state-of-the art seismic processing techniques and would be made openly available to the community, providing a high-quality data set illuminating the regional subsurface architecture all along the Cascadia Subduction Zone.

Aside from localized surveys conducted in 2012 by R/V *Langseth* using an 8-km streamer, no modern multi-channel seismic (MCS) data have been acquired at the Cascadia Subduction Zone. Data acquired prior to these surveys were collected in the 80's and 90's with much shorter streamers (2.6–4 km) and poorer quality sources and provide poor-to-no image of the earthquake fault interface at Cascadia. Long streamer (>8 km) MCS data represent major advances over the previous generation of MCS studies in the region for two primary reasons. (1) Data acquired with long-offset streamers support advanced techniques for noise and multiple suppression that enable imaging with improved clarity and resolution of the plate interface to much greater depths than previously obtained. (2) They enable construction of high-resolution, high-accuracy velocity models, which not only contribute to improved imaging via pre-stack depth migration, but can provide constraints on material properties at the megathrust that affect slip behavior. The proposed 15-km long streamer would provide significantly improved velocity determination from both reflection move-out based analysis and recorded refractions. The proposed study would also provide the first regional-scale characterization of the full length of the Cascadia Subduction Zone, enabling the first study of along-strike segmentation in megathrust properties. It would move the Cascadia megathrust zone from arguably one of the least well characterized heavily populated megathrust regions to one of the best.

Modern long-offset marine seismic reflection imaging techniques provide the best tools available for illuminating a subduction zone to the depths of the earthquake source region and below. They also provide constraints on geologic structure and material properties at the subduction fault that contribute to frictional state and variations in slip behavior along the fault. The overall goal of the seismic program proposed by L-DEO, UTIG, and WHOI is to acquire a regional grid of modern marine seismic reflection data spanning the entire Cascadia Subduction Zone to image how the geologic structure and properties of this subduction zone vary both along and across the margin. To achieve the project goals, the Principal Investigators (PI) Drs. S. Carbotte (L-DEO), P. Canales (WHOI), and S. Han (UTIG) propose to utilize 2-D seismic reflection capabilities of R/V *Langseth* and OBSs and OBNs.

2.1.2 Proposed Activities

2.1.2.1 Location of the Survey Activities

The proposed survey would occur within ~42–51°N, ~124–130°W. Representative survey tracklines are shown in Figure 1. As described further in this document, however, some deviation in actual track lines, including the order of survey operations, could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, for the surveys, the tracklines could occur anywhere within the coordinates noted above. The surveys are proposed to occur within Exclusive Economic Zones (EEZ) of the U.S. and Canada, as well as in U.S. state waters and Canadian Territorial Waters, ranging in depth 60–4400 m.

2.1.2.2 Description of Activities

The procedures to be used for the proposed marine geophysical surveys would be similar to those used during previous surveys by L-DEO and would use conventional seismic methodology. The survey would involve one source vessel, R/V *Langseth*, which would tow a 36-airgun array with a discharge volume of ~6600 in^3 at a depth of 12 m, and a shot interval of 37.5 m (~17 s). The receiving system would consist of a 15-km long hydrophone streamer. OBSs and OBNs would be deployed from a second vessel, R/V *Oceanus*; this OBS program would leverage the seismic surveys by R/V *Langseth*.

As the airgun arrays are towed along the survey lines, the hydrophone streamer would transfer the data to the on-board processing system; the OBSs and OBNs would receive and store the returning acoustic signals internally for later analysis. Approximately 6540 km of transect lines would be surveyed in the Northeast Pacific Ocean. Most of the survey (69%) would occur in deep water (>1000 m), 28% would occur in intermediate water (100–1000 m deep), and ~3% would take place in shallow water <100 m deep. Approximately 3.6% of the transect lines (234 km) would be undertaken in Canadian Territorial Waters, with most effort in intermediate waters.

Long 15-km-offset MCS data would be acquired along numerous 2-D profiles oriented perpendicular to the margin and located to provide coverage in areas inferred to be rupture patches during past earthquakes and their boundary zones. The survey would also include several strike lines including one continuous line along the continental shelf centered roughly over gravity-inferred fore-arc basins to investigate possible segmentation near the down-dip limit of the seismogenic zone. The margin normal lines would extend ~50 km seaward of the deformation front to image the region of subduction bend faulting in the incoming oceanic plate, and landward of the deformation front to as close to the shoreline as can be safely maneuvered. It is proposed that the southern transects off Oregon are acquired first, followed by the profiles off Washington and Vancouver Island, B.C.

In addition to the operation of the airgun array, a multibeam echosounder (MBES), sub-bottom profiler (SBP), and Acoustic Doppler Current Profiler (ADCP) would be operated from R/V *Langseth* continuously during the seismic surveys, but not during transit to and from the survey area. All planned geophysical data acquisition activities would be conducted by L-DEO with on-board assistance by the scientists who have proposed the studies. The vessel would be self-contained, and the crew would live aboard the vessel.

2.1.2.3 Schedule

The proposed surveys would be expected to last for 40 days, including ~37 days of seismic operations, 2 days of equipment deployment, and 1 day of transit. R/V *Langseth* would likely leave out of Newport, OR, and return to port in Seattle, WA, during late spring/summer 2021. As R/V *Langseth* is a national asset, NSF and L-DEO strive to schedule its operations in the most efficient manner possible; schedule efficiencies are achieved when regionally occurring research projects are scheduled consecutively and non-operational transits are minimized. Because of the nature of the NSF merit review process and the long timeline associated with the ESA Section 7 consultation and IHA processes, not all research projects or vessel logistics are identified at the time the consultation documents are submitted to federal regulators; typically, however, these types of details, such as port arrival/departure locations, are not a substantive component of the consultations. The ensuing analysis (including take estimates) focuses on the time of the survey (late spring/summer); the best available species densities for that time of the year have been used.

2.1.2.4 Vessel Specifications

R/V *Langseth* is described in § 2.2.2.1 of the PEIS. The vessel speed during seismic operations would be ~4.2 kt (~7.8 km/h).

R/V *Oceanus* would be used to deploy OBSs and OBNs. R/V *Oceanus* has a length of 54 m, a beam of 10 m, and a draft of 5.3 m. The ship is powered by one EMD diesel engine, producing 3000 hp, which drives the single screw propeller. The vessel also has a 350 hp bowthruster. The cruising speed is 20 km/h, the endurance is 30 days, and the range is ~13,000 km.

Other details of R/V *Oceanus* include the following:

Owner:	National Science Foundation
Operator:	Oregon State University
Flag:	United States of America
Date Built:	1975
Gross Tonnage:	261
Accommodation Capacity:	25 including ~13 scientists

2.1.2.5 Airgun Description

During the surveys, R/V *Langseth* would tow four strings with 36 airguns (plus 4 spares). During the surveys, all four strings totaling 36 active airguns with a total discharge volume of 6600 in^3, would be used. The airgun array is described in § 2.2.3.1 of the PEIS; the airgun configuration is illustrated in Figure 2-11 of the PEIS. The array would be towed at a depth of 12 m, and the shot interval would be 37.5 m.

2.1.2.6 OBS and OBN Description

The OBSs would consist of short-period multi-component OBSs from the Ocean Bottom Seismometer Instrument Center (OBSIC) and a large-*N* array of OBNs from a commercial provider to record shots along ~10 margin-perpendicular profiles. OBSs would be deployed at 10-km spacing along ~10 profiles from Vancouver Island to Oregon, and OBNs would be deployed at a 500-m spacing along a portion of three profiles off Oregon. Two OBS deployments would occur with a total of 115 instrumented locations. One deployment consisting of 60 OBSs to instrument six profiles off Oregon, and a second deployment of 55 OBSs to instrument four profiles off Washington and Vancouver Island. The first deployment off Oregon would occur prior to the start of the proposed survey, after which R/V *Langseth* would acquire data in the southern portion of the study area. R/V *Oceanus* would start recovering the OBSs from deployment 1, and then re-deploy 55 OBSs off Washington and Vancouver Island, so that R/V *Langseth* can acquire data in the northern portion of the survey area. The OBSs have a height and diameter of ~1 m, and most would have an ~80 kg anchor made of steel. OBSs deployed within the OCNMS (three total) would have a concrete anchor, ~0.3 m x 0.3 m x 0.16 m, weighing ~36 kg in air and ~20 kg in water. The concrete anchors disintegrate faster than the steel anchors. While the concrete anchors have some steel embedded as an attachment point for the OBS, they would degrade, mainly to sand.

A total of 350 nodes would be deployed: 179 nodes along one transect off northern Oregon, 1007 nodes along a second transect off central Oregon, and 64 nodes along a third transect off southern Oregon. The nodes are not connected to each other; each node is independent from each other, and there are no cables attached to them. Each node has internal batteries; all data is recorded and stored internally. The nodes weigh 21 kg in air (9.5 kg in water). As the OBNs are small (330 mm x 289 mm x 115 mm), compact, not buoyant, and lack an anchor-release mechanism, they cannot be deployed/recovered by free-fall as with the OBSs. The nodes would be deployed and retrieved using a tethered remotely operated vehicle (ROV);

the ROV would be deployed from R/V *Oceanus*. OBNs would be deployed ~17 days prior to the start of the R/V *Langseth* cruise. The ROV would be fitted with a skid with capacity for 32 units, lowered to the seafloor, and towed at a speed of 0.6 kt at 5–10 m above the seafloor between deployment sites. After the 32 units are deployed, the ROV would be retrieved, the skid would be reloaded with another 32 units, and sent back to the seafloor for deployment, and so on. The ROV would recover the nodes 3 days after the completion of the R/V *Langseth* cruise. The nodes would be recovered one by one by a suction mechanism.

2.1.2.7 Additional Acoustical Data Acquisition Systems

Along with the airgun operations, two additional acoustical data acquisition systems (an MBES and SBP) would be operated from R/V *Langseth* during the proposed surveys, but not during transits to/from the survey site and port. The ocean floor would be mapped with the Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP. These sources are described in § 2.2.3.1 of the PEIS. To retrieve OBSs, an acoustic release transponder (pinger) is used to interrogate the instrument at a frequency of 8–11 kHz, and a response is received at a frequency of 11.5–13 kHz. The burn-wire release assembly is then activated, and the instrument is released to float to the surface from the anchor which is not retrieved. However, OBSs would not be recovered by R/V *Langseth*.

2.1.3 Monitoring and Mitigation Measures

Standard monitoring and mitigation measures for seismic surveys are described in § 2.4.1.1 and 2.4.2 of the PEIS and would occur in two phases: pre-cruise planning and operations. The following sections describe the efforts during both stages for the proposed activities. Numerous papers have been published with recommendations on how to reduce anthropogenic sound in the ocean (e.g., Simmonds et al. 2014; Wright 2014; Dolman and Jasny 2015). Some of those recommendations have been taken into account here.

2.1.3.1 Planning Phase

As discussed in § 2.4.1.1 of the PEIS, mitigation of potential impacts from the proposed activities begins during the planning phase. Several factors were considered during the planning phase of the proposed activities, including:

***Energy Source*.—**Part of the considerations for the proposed marine seismic surveys was to evaluate whether the research objectives could be met with a smaller energy source. However, the scientific objectives for the proposed surveys could not be met using a smaller source. The full R/V *Langseth* source array is needed to reach the deep imaging targets of the megathrust and oceanic Moho under the continental margin (up to ~20 km bsl). This large source is also needed to ensure recording of refracted arrivals at large ranges of up to 200 km on the planned OBS array as well as an array of land stations that may be deployed.

***Survey Location and Timing*.—**The PIs worked with NSF to consider potential times to carry out the proposed surveys, key factors taken into consideration included environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, equipment, and optimal timing for other proposed seismic surveys using R/V *Langseth*. Although marine mammals, including baleen whales, are expected to occur regularly in the proposed survey area during the spring and summer, the peak migration period for gray whales is expected to occur before the start of the surveys. Late spring/summer is the most practical season for the proposed surveys based on operational requirements.

Changes to the location of proposed seismic transect were also made during consultation with NMFS, USFWS, and DFO. Off Washington and Oregon, all transect lines and the associated Level B ensonified areas (based on the 160-dB re 1µPa$_{rms}$ sound level) were moved out of high-density killer whale habitat and/or areas off Washington and B.C. in water <100 m depth. All lines off Washington were also moved out of the 100-m isobath to avoid part of the proposed critical habitat for killer whales and >21 km from shore to avoid sea otters takes. In addition, off Oregon, proposed transect lines and associated 160-dB ensonified areas around the lines were moved outside of potential sea otter habitat (within the 40-m isobath) off Newport, Cape Arago, and Cape Blanco. After discussions with Canadian Department of Fisheries and Oceans (DFO), transect lines and associated 160-dB ensonified areas were moved out of Canadian designated critical habitat for killer whales off Vancouver Island, B.C.

***Mitigation Zones*.—**During the planning phase, mitigation zones for the proposed marine seismic surveys using the 36-airgun array (at a tow depth of 12 m) were not derived from the farfield signature but based on modeling by L-DEO for both the exclusion zones (EZ) for Level A takes and full mitigation zones (160 dB re 1µPa$_{rms}$) for Level B takes. L-DEO model results were used to determine the 160-dB$_{rms}$ radius for the 36-airgun array and 40-in^3 airgun at a 12-m tow depth in deep water (>1000 m) down to a maximum depth of 2000 m, as animals are generally not anticipated to dive below 2000 m (Costa and Williams 1999).In the Draft EA, the radii for intermediate water depths (100–1000 m) were derived from the deep-water ones by applying a correction factor of 1.5. For shallow water (<100 m), radii were based on empirically derived measurements in the Gulf of Mexico (GoM) with scaling applied to account for differences in tow depth (see Appendix A).

However, after consultation with NMFS, the mitigation zones for the Level B (160-dB) threshold were revised based on a combination of empirical data and modeling. The background information and methodology for this are provided in Appendix A. The L-DEO model results were still used to determine the 160-dB$_{rms}$ radius for the 36-airgun array and 40-in^3 airgun (mitigation airgun) at a 12-m tow depth in deep water (>1000 m) down to a maximum depth of 2000 m. However, for the 36-airgun array, radii for intermediate-water depths (100–1000 m) and shallow water (<100 m) were derived from empirical data from Crone et al. (2014) with a scaling factor applied to account for differences in tow depth (see Appendix A). As Crone et al. (2014) did not collect empirical data for the 40-in^3 airgun, the radii for intermediate water and shallow water were derived as before.

Table 1 shows the distances at which the 160-dB re 1µPa$_{rms}$ sound levels are expected to be received for the 36-airgun array and the single (mitigation) airgun. The 160-dB level is the behavioral disturbance criterion (Level B) that is used by NMFS to estimate anticipated takes for marine mammals. Table 1 also shows the distances at which the 175-dB re 1µPa$_{rms}$ sound level is expected to be received for the 36-airgun array and a single airgun; this level is used by NMFS, as well as the U.S. Navy (USN 2017), to determine behavioral disturbance for turtles.

The thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury) for marine mammals and sea turtles for impulsive sounds use dual metrics of cumulative sound exposure level (SEL$_{cum}$ over 24 hours) and peak sound pressure levels (SPL$_{flat}$). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., harbor porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW) (NMFS 2016a, 2018a), and sea turtles (USN 2017). Per the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* (NMFS 2016a, 2018a), the largest distance of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate Level A takes and threshold distances for marine mammals. Here, SEL$_{cum}$ is used for turtles and LF cetaceans, and Peak SPL is used for all other marine mammal hearing groups (Table 2).

TABLE 1. Level B. Predicted distances to which sound levels ≥160-dB and ≥175-dB re 1 μPa$_{rms}$ could be received during the proposed surveys in the Northeast Pacific Ocean. The 160-dB criterion applies to all hearing groups of marine mammals and the 175-dB criterion applies to sea turtles.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level	Predicted distances (in m) to the 175-dB Received Sound Level
Single Bolt airgun, 40 in^3	12	>1000 m	431[1]	77[1]*
		100–1000 m	647[2]	116[2]
		<100 m	1,041[3]	170[3]
4 strings, 36 airguns, 6600 in^3	12	>1000 m	6,733[1]	1,864[1]
		100–1000 m	9,468[4]	2,542[4]
		<100 m	12,650[4]	3,924[4]

[1] Distance is based on L-DEO model results. [2] Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths. [3] Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth. [4] An EZ of 100 m would be used as the shut-down distance for sea turtles in all water depths.
[4] Based on empirical data from Crone et al. (2014); see Appendix A for details.

TABLE 2. Level A threshold distances for different marine mammal hearing groups and sea turtles for the 36-airgun array. Consistent with NMFS (2016a, 2018a), the largest distance (in bold) of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate Level A takes and threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups					
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles
PTS SEL$_{cum}$	**426.9**	0	1.3	13.9	0	**20.5**
PTS Peak	38.9	**13.6**	**268.3**	**43.7**	**10.6**	10.6

This document was prepared in accordance with the current National Oceanic and Atmospheric Administration (NOAA) acoustic practices, and the monitoring and mitigation procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013a), Wright (2014), Wright and Cosentino (2015), and Acosta et al. (2017). For other recent high-energy seismic surveys conducted by L-DEO, NMFS required protected species observers (PSOs) to establish and monitor a 500-m EZ for power downs and to monitor an additional 500-m buffer zone beyond the EZ for most marine mammals. A 1500-m EZ was established for beaked whales, and dwarf and pygmy sperm whales. A power down required the reduction of the full array to a single 40-in^3 airgun; a 100-m EZ was established and monitored for shut downs of the single airgun. However, based on recent direction from NMFS, power downs would not be allowable under the IHA; shut downs would be implemented for marine mammals within the designated EZ. A power down would be implemented for sea turtles or diving ESA-listed seabirds in U.S. waters. A 100-m EZ would be used for shut downs of the single airgun during power downs for sea turtles and seabirds. Enforcement of mitigation zones via power and shut downs would be implemented as described below.

2.1.3.2 Operational Phase

Marine mammals and sea turtles are known to occur in the proposed survey area. However, the number of individual animals expected to be approached closely during the proposed activities are expected to be relatively small in relation to regional population sizes. To minimize the likelihood that potential impacts could occur to the species and stocks, monitoring and mitigation measures proposed during the operational phase of the proposed activities, which are consistent with the PEIS and past IHA and incidental take statement (ITS) requirements, include:

1. monitoring by PSOs for marine mammals, sea turtles, and ESA-listed seabirds diving near the vessel, and observing for potential impacts of acoustic sources on fish;
2. passive acoustic monitoring (PAM);
3. PSO data and documentation; and
4. mitigation during operations (speed or course alteration; power-down, shut-down, and ramp-up procedures; and special mitigation measures for rare species, species concentrations, and sensitive habitats).

Five independently contracted PSOs would be on board the survey vessel with rotating shifts to allow two observers to monitor for marine species during daylight hours, and one observer to conduct PAM during day- and night-time seismic operations. The proposed operational mitigation measures are standard for all high-energy seismic cruises, per the PEIS, and are described in the IHA application, and therefore are not discussed further here. Special mitigation measures were considered for this cruise. In order to prevent ship strikes, vessel speed would be reduced to 10 kt or less when mother/calf pairs, pods, or large assemblages of marine mammals are observed (during seismic operations vessel speed would only be ~4.2 kt). Vessels would maintain a separation distance of 500 m from any right whale, 400 m from killer whales in Canadian waters between the U.S. EEZ and just north of Barkley Sound, 200 m from killer whales in all other Canadian waters, 100 m from large whales (mysticetes and sperm whales) in U.S. waters and all cetaceans except killer whales in Canadian waters, and 50 m from all other marine mammals in U.S. waters, with an exception for those animals that voluntarily approach the vessel (i.e., bow-riding dolphins).

It is unlikely that concentrations of large whales would be encountered within the 160-dB isopleth, but if a group of six or more is encountered, a shut down would be implemented at any distance. In addition, a shut down at any distance would be implemented for a large whale with calf, North Pacific Right Whale, and all killer whales, whether they are detected visually or acoustically. Shut downs within an EZ of 1500 m would occur for pygmy sperm, dwarf sperm, and beaked whales. In U.S. waters, the designated EZ for shut downs for other marine mammals (with the exception of bow-riding dolphins) is 500 m. In Canadian waters, the designated EZ for shut downs for other marine mammal species and sea turtles is 1000 m, except for sperm whales, for which the EZ is 1500 m.

Additional mitigation measures for the endangered southern resident killer whale stock would be implemented. The "Management measures to protect southern resident killer whales" released by DFO would be adhered to, and are included in the summary above regarding separation distances. . North of Tillamook Head, OR, there would be no night-time seismic operations in water <200 m deep; survey operations would occur in daylight hours only (i.e., from 30 minutes prior to sunrise through 30 minutes following sunset) to ensure the ability to use visual observation as a detection-based mitigation tool and to implement shut down procedures for species or situations with additional shut-down requirements outlined above (e.g., killer whale of any ecotype, North Pacific right whale, aggregation of six or more large whales, large whale with a calf).

Additionally, while R/V *Langseth* is surveying north of Tillamook Head OR, in waters 200 m deep or less, and when operating within the OCNMS and Makah Tribal U&A Fishing Areas, a secondary monitoring vessel with additional PSOs would be employed to observe ahead of and communicate with R/V *Langseth* regarding presence of killer whales and other cetaceans for assistance with implementation of mitigation measures. This secondary vessel would travel ~5 km ahead of R/V *Langseth*, and two PSOs would be on watch during all survey operations to alert PSOs on R/V *Langseth* of any marine mammal sightings so that they may be prepared to initiate shut down, if necessary. Each day of survey operations, L–DEO would contact NMFS Northwest Fisheries Science Center, NMFS West Coast Region, The Whale Museum, Orca Network, Canada's DFO, the Makah Tribe, and/or other sources to obtain near real-time reporting for the whereabouts of Southern Resident killer whales.

With the proposed monitoring and mitigation provisions, potential effects on most, if not all, individuals would be expected to be limited to minor behavioral disturbance. Those potential effects would be expected to have negligible impacts both on individual marine mammals and on the associated species and stocks. Ultimately, survey operations would be conducted in accordance with all applicable U.S. federal regulations, including IHA and ITS requirements.

2.2 Alternative 1: No Action Alternative

An alternative to conducting the Proposed Action is the "No Action" alternative, i.e., do not issue an IHA and do not conduct the research operations (Table 3). Under the "No Action" alternative, NSF would not support L-DEO to conduct the proposed research operations. From NMFS' perspective, pursuant to its obligation to grant or deny permit applications under the MMPA, the "No Action" alternative entails NMFS denying the application for an IHA. If NMFS were to deny the application, L-DEO would not be authorized to incidentally take marine mammals. If the research was not conducted, the "No Action" alternative would result in no disturbance to marine mammals attributable to the Proposed Action. Although the No-Action Alternative is not considered a reasonable alternative because it does not meet the purpose and need for the Proposed Action, it is included and carried forward for analysis in § 4.3.

2.3 Alternatives Considered but Eliminated from Further Analysis

Table 3 provides a summary of the Proposed Action, alternative, and alternatives eliminated from further analysis.

2.3.1 Alternative E1: Alternative Location

At the Cascadia Subduction Zone, the slow ongoing descent of the Juan de Fuca plate beneath the northwestern coast of North America has generated large earthquakes and associated tsunamis in the past in this heavily populated region of the Pacific Northwest. This would be the first seismic imaging investigation spanning nearly the entire length of the Cascadia Subduction Zone and would move the Cascadia megathrust zone from arguably one of the least well characterized heavily populated megathrust regions to one of the best. The overarching goal of the study is to use modern MCS data to characterize subducting plate and accretionary wedge structure, and properties of the megathrust, along the full length of the Cascadia Subduction Zone. This regional characterization would be used to determine whether there are any systematic relationships among upper and lower plate properties, paleorupture segmentation, and along-margin variations in present-day coupling at Cascadia. The data would also be used to characterize down-dip variations along the megathrust that may be linked to transitions in fault properties, from the updip region near the deformation front, which is of most interest for tsunamigenesis, to near shore where the downdip transition in the locked zone may reside.

TABLE 3. Summary of Proposed Action, Alternative Considered, and Alternatives Eliminated.

Proposed Action	Description
Proposed Action: Conduct marine geophysical surveys and associated activities in the Northeast Pacific Ocean	Under this action, research activities are proposed to study earth processes and would involve 2-D seismic surveys. Active seismic portions would be expected to take ~39 days, plus 1 day for transit. Additional operational days would be expected for equipment deployment, maintenance, and retrieval; weather; marine mammal activity; and other contingencies. The affected environment, environmental consequences, and cumulative impacts of the proposed activities are described in § III and IV. The standard monitoring and mitigation measures identified in the PEIS would apply, along with any additional requirements identified by regulating agencies in the U.S. and Canada. All necessary permits and authorizations, including an IHA, would be requested from regulatory bodies.
Alternatives	Description
Alternative 1: No Action	Under this Alternative, no proposed activities would be conducted, and seismic data would not be collected. While this alternative would avoid impacts to marine resources, it would not meet the purpose and need for the Proposed Action. Geological data of scientific value and relevance increasing our understanding of Cascadia Subduction Zone, adding to the comprehensive assessment of geohazards for the Pacific Northwest such as earthquakes and tsunamis, and for the development of an earthquake early warning network, would not be collected. The collection of new data, interpretation of these data, and introduction of new results into the greater scientific community and applicability of these data to other similar settings would not be achieved. No permits and authorizations, including an IHA, would be needed from regulatory bodies, as the Proposed Action would not be conducted.
Alternatives Eliminated from Further Analysis	Description
Alternative E1: Alternative Location	At the Cascadia Subduction Zone, the slow ongoing descent of the Juan de Fuca plate beneath the northwestern coast of North America has generated large earthquakes and associated tsunamis in the past in this heavily populated region of the Pacific Northwest. This would be the first seismic imaging investigation spanning nearly the entire length of the Cascadia Subduction Zone and would move the Cascadia megathrust zone from arguably one of the least well characterized heavily populated megathrust regions to one of the best. The acquired data would add to the comprehensive assessment of geohazards for the Northeast Pacific region. The proposed science underwent the NSF merit review process, and the science, including the site location, was determined to be meritorious.
Alternative E2: Use of Alternative Technologies	Under this alternative, L-DEO would use alternative survey techniques, such as marine vibroseis, that could potentially reduce impacts on the marine environment. Alternative technologies were evaluated in the PEIS, § 2.6. At this time, however, these technologies are still not feasible, commercially viable, or appropriate to meet the Purpose and Need.

2.3.2 Alternative E2: Use of Alternative Technologies

As described in § 2.6 of the PEIS, alternative technologies to the use of airguns were investigated to conduct high-energy seismic surveys. At this time, these technologies are still not feasible, commercially viable, or appropriate to meet the Purpose and Need. Additional details about these technologies are given in the Final USGS EA (RPS 2014a).

III AFFECTED ENVIRONMENT

As described in the PEIS, Chapter 3, the description of the affected environment focuses only on those resources potentially subject to impacts from the actions being proposed here; other activities (e.g., land-based component) will be analyzed under separate review. The discussion of the affected environment (and associated analyses) focuses mainly on those related to marine biological resources, as the proposed short-term activity has the potential to impact marine biological resources within the project area. These resources are identified in § III, and the potential impacts to these resources are discussed in § IV. Initial review and analysis of the proposed Project activity determined that the following resource areas did not require further analysis in this EA:

- *Air Quality/Greenhouse Gases*—Project vessel emissions would result from the proposed activity; however, these short-term emissions would not result in any exceedance of Federal Clean Air standards. Emissions would be expected to have a negligible impact on the air quality within the proposed survey area;
- *Land Use*—All activities are proposed to occur in the marine environment. No changes to current land uses or activities in the proposed survey area would result from the Project;
- *Safety and Hazardous Materials and Management*—No hazardous materials would be generated or used during the proposed activities. All Project-related wastes would be disposed of in accordance with international, U.S. state, and federal requirements;
- *Geological Resources (Topography, Geology and Soil)*—The proposed Project would result in very minor disturbances to seafloor sediments from OBN and OBS deployments during the surveys; small anchors would not be recovered. The proposed activities would not significantly impact geologic resources;
- *Water Resources*—No discharges to the marine environment that would adversely affect marine water quality are expected in the Project area. Therefore, there would be no impacts to water resources resulting from the proposed Project activity;
- *Terrestrial Biological Resources*—All proposed Project activities would occur in the marine environment and would not impact terrestrial biological resources;
- *Visual Resources*—No visual resources would be expected to be negatively impacted as the majority of the peration area is outside of the land and coastal viewshed.
- *Socioeconomic and Environmental Justice*—Implementation of the proposed project would not affect, beneficially or adversely, socioeconomic resources, environmental justice, or the protection of children. No changes in the population or additional need for housing or schools would occur. Although there are a number of shore-accessible SCUBA diving sites along the coasts of Oregon, Washington, and B.C. (see Section 3.9), the proposed activities would occur in water depths >60 m, outside the range for recreational SCUBA diving. Human activities in the area around the survey vessel would be limited to fishing activities, NMFS trawl surveys, other vessel traffic, and whale watching. However, no significant impacts on fishing, vessel traffic, or whale watching would be anticipated particularly because of the short duration of the proposed activities. Fishing and potential impacts to fishing are described in further detail in Sections III and IV, respectively. No other socioeconomic impacts would be anticipated as result of the proposed activities.

3.1 Oceanography

The proposed survey area is located in the northeastern Pacific Ocean. The North Pacific Current (NPC) is a warm water current that flows west to east between 40ºN and 50ºN. The NPC forms the northern part of the clockwise-flowing subtropical gyre; to the north of it, the subarctic gyre flows counterclockwise (Escorza-Treviño 2009). The convergence zone of the subarctic and central gyres, known as the Subarctic Boundary, crosses the western and central North Pacific Ocean at 42ºN (Escorza-Treviño 2009). It is in that area that the change in abundance of cold-water vs. warm-water species is the greatest (Escorza-Treviño 2009). In the eastern Pacific, the NPC splits into the northward flowing Alaska Current and the southward flowing California Current (Escorza-Treviño 2009). The California Current system nutrifies offshore waters by mixing with water from the shelf edge (Buchanan et al. 2001).

The northern portion of the proposed survey area (i.e., Vancouver Island) is located within the Gulf of Alaska Large Marine Ecosystem (LME); this LME is classified as a Class II, moderately productive (150–300 $gC/m^2/y$) ecosystem (Aquarone and Adams 2009a). The southern portion of the proposed survey area (Washington and Oregon) is located within the California Current LME. This LME is considered a Class III low productivity ecosystem (<150 $gC/m^2/y$) although seasonal upwelling of cold nutrient-rich water in this region generate localized areas of high productivity supporting fisheries (Aquarone and Adams 2009b). Winds blowing toward the equator cause upwelling during March–November and are strongest over the main flow of the California Current which is 200–400 km offshore (Longhurst 2007). Persistent eddies in the summer in some locations, like the Strait of Juan de Fuca, can transport upwelling waters up to several hundred kilometers offshore (Longhurst 2007). Even in winter, cold upwelled water "tongues" can extend offshore for hundreds of kilometers, increasing nutrient levels offshore (Longhurst 2007). The highest productivity occurs in May–June (Longhurst 2007). Acoustic backscatter surveys within the California Current LME showed that fish and zooplankton are associated with shallow bathymetry in this region; the highest densities were located in water <4000 m deep (Philbrick et al. 2003).

Numerous publications have examined the role of climate shifts as a forcing agent on species and community structure of the North Pacific Ocean (e.g., Francis and Hare 1994; Klyashtorin 1998; McGowan et al. 1998; Hollowed et al. 1998; Hare and Mantua 2000). Regime shifts that might impact productivity in the region include the Pacific Decadal Oscillation (PDO) and the El Niño Southern Oscillation. The PDO is similar to a long-lived El Niño-like pattern of climate variability; it is mainly evident in the North Pacific/North American area, whereas El Niños are typical in the tropics (Mantua 1999). PDO "events" persist for 20–30 years, whereas typical El Niño events persist for 6–18 months (Mantua 1999). In the past century, there have been two PDO cycles: "cool" PDO regimes during 1890–1924 and 1947–1976, and "warm" PDO regimes during 1925–1946 and 1977–the mid-1990s (Mantua et al. 1997; Minobe 1997). The latest "cool" period appears to have occurred during the mid-1990s until 2013 (NOAA 2019a).

A mass of warm water, referred to as "the Blob", formed in the Gulf of Alaska during autumn 2013 and grew and spread across the majority of the North Pacific and Bering Sea during spring and summer 2014, resulting in sea surface temperature anomalies ≥4ºC across the region (Peterson et al. 2016). During autumn 2014, decreased upwelling winds caused a portion of this warm water to travel eastward towards the continental shelf off eastern Alaska and the Pacific Northwest, making the sea surface temperature pattern associated with the Blob resemble a "warm" or "positive" PDO pattern (Peterson et al. 2016). Ongoing effects from "the Blob" were further perturbed by a major El Niño arriving from the south and affecting the region during 2015 and 2016, the combination of which reduced the ecosystem's productivity and altered marine community structure for several years (Brodeur et al. 2018). As of May 2016, sea surface temperature anomalies in the outer shelf waters off Oregon remained 2ºC higher, with indications the trend would likely continue well into 2017 (Peterson et al. 2016). Changes in the eastern North Pacific Ocean marine ecosystem have been correlated with changes in the PDO. Warm PDOs showed increased coastal productivity in Alaska and decreased productivity off the U.S. west coast, whereas the opposite north-south pattern of marine ecosystem productivity was seen during cold PDOs (Mantua 1999).

During late 2018, sustained unseasonably warm conditions likely caused the formation of a new mass of warm water encompassing a large portion of the Pacific Ocean, emulating "the Blob" and dubbed the "Son of the Blob" (Britten 2018). Such warm-water masses are speculated to be linked to climate change and have been correlated with warmer weather on land, deceased whales and extreme mortality events of other higher-trophic level organisms, occurrences of uncommon marine taxa, widespread toxic algal blooms, and poor feeding conditions for many fish species (Britten 2018; Brodeur et al. 2018). A significant shift in prey availability and feeding habits was observed for anchovy, sardine, mackerel, herring, and smelt species in the northern California Current Ecosystem (CCE) off the Washington and Oregon coasts (Brodeur et al. 2018). While the effects of "the Blob" or the "Son of the Blob" are not yet fully understood, the formation of warm water patches are increasingly common in the Pacific Ocean off the western Canadian and American coasts (Britten 2018).

3.2 Protected Areas

3.2.1 Critical Habitat in the U.S.

Several habitats near or within the proposed survey area have been specifically identified as important to U.S. ESA-listed species, including critical habitat for marine mammals, sea turtles, seabirds, and fish. Although there is critical habitat adjacent to the survey area for the ***threatened*** Pacific Coast population of western snowy plover and the ***threatened*** marbled murrelet, this habitat is strictly terrestrial and would not be affected by the proposed activities.

***Steller Sea Lion Critical Habitat*.—**Federally designated critical habitat for Steller sea lions in Oregon and California includes all rookeries (NMFS 1993). Although the Eastern Distinct Population Segment (DPS) was delisted from the ESA in 2013, the designated critical habitat remains valid (NOAA 2019b). The critical habitat in Oregon is located along the coast at Rogue Reef (Pyramid Rock) and Orford Reef (Long Brown Rock and Seal Rock; see Fig. 1). The critical habitat area includes aquatic zones that extend 0.9 km seaward and air zones extending 0.9 km above these terrestrial and aquatic zones (NMFS 1993). The Orford Reef and Rogue Reef critical habitats are located ~13.5 km and ~17 km from the nearest proposed seismic transect line, respectively.

Southern Resident Killer Whale Critical Habitat*.—**Critical habitat for the ***endangered Eastern North Pacific Southern Resident stock of killer whales is defined in detail in the Code of Federal Regulations (NMFS 2006). Critical habitat currently includes three specific marine areas of Puget Sound, WA: the Summer Core Area, Puget Sound, and the Strait of Juan de Fuca. The critical habitat includes all waters relative to a contiguous shoreline delimited by the line at a depth of 6.1 m relative to extreme high water. The western boundary of the Strait of Juan de Fuca Area is Cape Flattery, WA (48.38°N; 124.72°W), which is ~49 km from the closest seismic transect line (Fig. 1). None of the proposed transect lines and associated ensonified areas occur within designated critical habitat, and all tracklines are >21 km from shore.

In January 2014, NMFS received a petition requesting an expansion to the Southern Resident killer whale critical habitat to include Pacific Ocean marine waters along the U.S. west coast from Cape Flattery, WA, to Point Reyes, CA, extending ~76 km offshore; NMFS released a 12-month finding in February 2015 accepting the validity of a critical habitat expansion (NMFS 2015a). Although no revisions have yet been made to the critical habitat, NMFS recently issued a proposed rule for the expansion of critical habitat to include U.S. coastal waters between the 6.1-m and 200-m isobath from the border with Canada south to Point Sur, CA (NMFS 2019a). Some of the proposed survey lines enter the proposed critical habitat.

All originally-proposed transect lines and their associated 160-dB ensonified areas have been moved away from (1) high-density killer whale habitat along the coasts of Oregon and Washington, and/or (2) shallow water <100 m deep off Washington, as required by NMFS, and shallow water <100 m deep off B.C. In addition, most tracklines in water <100 m deep off Oregon were eliminated, except for a section of the coast with a larger protrusion of shallow-water topography. Airgun operations in water 100–200 m deep north of Tillamook Head, OR, would only occur during the daytime, and a secondary monitoring vessel would be used to look for killer whales ahead of the survey. Each day of survey operations, L–DEO would contact NMFS Northwest Fisheries Science Center, NMFS West Coast Region, The Whale Museum, Orca Network, Canada's DFO or other sources to obtain near real-time reporting for the whereabouts of Southern Resident killer whales.

Humpback Whale Critical Habitat*.—**On 21 April 2021, NMFS designated critical habitat in nearshore waters of the North Pacific Ocean for the ***endangered Central America and Western North Pacific DPSs and the ***threatened*** Mexico DPS of humpback whale (NMFS 2021a). Critical habitat for the Central America and Mexico DPSs includes waters within the CCE off the coasts California, Oregon, and Washington (Fig. 1). Off Washington, critical habitat includes waters from the 50-m to 1200-m isobaths, as well as the Strait of Juan de Fuca eastward to Angeles Point; however, there is an exclusion area of 1461 nmi^2 around the Navy's Quinault Range Site. Off Oregon, the critical habitat spans from the 50-m to 1200-m isobath, except for areas south of 42.17°N, where the offshore boundary is at the 2000-m isobath. There is also critical habitat for the Mexico and Western Pacific DPSs in Alaska waters (NMFS 2021a). No transect lines or ensonified areas would occur within the 100-m isobath between Tillamook Head, OR, and Barkley Sound; most of the survey and ensonified areas off Oregon are also outside the 100-m isobath.

Leatherback Sea Turtle Critical Habitat*.—**In January 2012, NMFS designated critical habitat for the ***endangered leatherback sea turtle along the west coast of the U.S. (NMFS 2012). The critical habitat includes marine areas of ~64,760 km^2 from Cape Flattery, WA, to Cape Blanco, OR, and ~43,798 km^2 off California (NMFS 2012). The survey area east of the 2000-m contour is located within critical habitat (see Fig. 1).

Green Sturgeon Critical Habitat*.—**Coastal U.S. marine critical habitat for the ***threatened Southern DPS of North American green sturgeon includes waters within ~109 m (60 fathoms) depth from Monterey Bay, CA, north to Cape Flattery, WA, to its U.S. boundary, encompassing 29,581 km^2 of marine habitat (NMFS 2009). The proposed survey area that is located in water depths less than 109 m occurs within this critical habitat (see Fig. 1). Between Tillamook Head and Barkley Sound, all transect lines and 160-dB ensonified areas would occur outside of the 100-m isobath. Off Oregon, the majority of transect lines are located outside of the 109-m isobath, but some effort on Hecate Bank is proposed to occur in water depths 60–109 m.

Rockfish Critical Habitat*.—**Critical habitats have been designated for the ***threatened Puget Sound/Georgia Basin DPS of yelloweye rockfish and for the ***endangered*** Puget Sound/Georgia Basin DPS of bocaccio (NMFS 2014). However, no critical habitat occurs within the proposed survey area.

Pacific Eulachon Critical Habitat*.—**Critical habitat has been designated for the ***threatened Southern DPS of Pacific eulachon/smelt for Washington and Oregon. Most of the critical habitat occurs in freshwater rivers and creeks, but some does include estuarine waters (NMFS 2011a; NOAA 2019b). However, none of the proposed seismic transect lines enter critical habitat.

***Salmonid Critical Habitat*.—**Critical habitat has been designated for a number of ESA-listed salmonid species or evolutionary significant units (ESU) for Washington and Oregon (see Section 3.7.1, Table 6, for list of species). Most of the critical habitat occurs in freshwater rivers and creeks, but some of it includes nearshore marine waters (NOAA 2019b). However, none of the proposed seismic transect enter critical habitat.

3.2.2 Critical Habitat in Canada

Several habitats near or within the proposed survey area have been identified as important under Canada's *Species at Risk Act* (SARA) to listed species, including critical habitat for two populations of marine mammals and northern abalone. Although critical habitat was previously designated for the humpback whale (DFO 2013a), this is no longer in effect as the humpback whale was down-listed to *special concern* under SARA. Critical habitat for the ***threatened*** marbled murrelet occurs adjacent to the study area, but this habitat is strictly terrestrial and would not be affected by the proposed activities. Critical habitat is defined under SARA as the "habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as such in the recovery strategy or action plan for the species" (DFO 2018a). According to DFO, critical habitat could include areas used for spawning, rearing young, feeding and migration, depending on the species and may not be destroyed (DFO 2018a).

***Southern Resident Killer Whale Critical Habitat*.—**Critical habitat has been designated in the trans-boundary waters in southern B.C., including the southern Strait of Georgia, Haro Strait, and Strait of Juan de Fuca (DFO 2018a). The continental shelf waters off southwestern Vancouver Island, including Swiftsure and La Pérouse Banks have also been designated as critical habitat (DFO 2018a). The critical habitat has features such as prey availability (specifically chinook and chum salmon), suitable acoustic environment, water quality, and physical space that provide areas for feeding, foraging, reproduction, socializing, and resting (DFO 2018a). After consultations with DFO, none of the proposed transect lines or their associated 160-dB ensonified areas would enter the critical habitat on Swiftsure and La Pérouse banks (see Fig. 1). In addition, in 2020, DFO released 'Management measures to protect southern resident killer whales, that specify that a minimum distance of 200 m must be kept from killer whales in all Canadian Pacific waters, except for designated areas (including critical habitat) in which a minimum distance of 400 m must be kept (DFO 2021). The R/V *Langseth* would not approach any killer whales within 200 m. In addition, during seismic acquisition, the vessel would be traveling at a speed of 4.2 kt which is below the recommended speed when killer whales are within 1000 m. If practicable, R/V *Langseth* would slow down to 7 kt while transiting to and from the survey area, if killer whales are within 1000 m.

***Northern Resident Killer Whale Critical Habitat*.—**Critical habitat has been designated in Johnstone Strait and southeastern Queen Charlotte Strait. The continental shelf waters off southwestern Vancouver Island, including Swiftsure and La Pérouse Banks, have also been designated as critical habitat, as well as western Dixon Entrance along the north coast of Graham Island, Haida Gwaii (DFO 2018a). The critical habitat has features such as prey availability (specifically chinook and chum salmon), appropriate acoustic environment, water quality, and physical space, and suitable physical habitat that provide areas for feeding, foraging, reproduction, socializing, resting, and beach rubbing (DFO 2018a). After consultations with DFO, none of the proposed transect lines or their associated 160-dB ensonified areas would enter the critical habitat on Swiftsure and La Pérouse Banks (see Fig. 1).

***Northern Abalone Critical Habitat*.—**Critical habitat for northern abalone has been identified within four distinct geospatial areas that include Barkley Sound and surrounding waters on the southwest coast of Vancouver Island (see Fig. 1), the west and east coasts of Haida Gwaii, and the north and central coasts of B.C. (DFO 2012). The west and east coasts of Haida Gwaii and the north and central coasts of mainland B.C. habitats were identified due to their historical significance in production to the former commercial abalone fishery; the Barkley Sound habitat was identified as an important rebuilding area (DFO 2012).

Abalone are typically found in shallow waters <10 m attached to hard substratum such as rocks, boulders, and bedrock (DFO 2012). Within the identified geographic boundaries, not all habitat comprises critical habitat, but rather only those areas with sites at least 20 m^2 in size with a density of ≥0.1 abalone/m^2 that contain the following physical attributes: appropriate primary substrate consisting of bedrock or boulders for attachment or secondary substrate including some cobble; water with salinity >30 ppt and moderate to high water exchange from tidal currents or wave action; presence of encrusting coralline algae such as *Lithothamnium* spp.; and the presence of macroalgae such as *Nereocystic*, *Macrocystic*, *Pterygophora*, or *Laminaria* spp. Encrusting coralline algae is a primary site of larval settlement and provides feeding and refuge grounds for juveniles (DFO 2012). The critical habitat is located at least 40 km from the closest seismic transect (see Fig. 1).

3.2.3 Other Conservation Areas in U.S. Waters

There are two portions of U.S. military land which are closed to access near the mouth of the Columbia River, referred to as Warrenton/Camp Rilea (USGS 2019). All conservation areas near the project area are listed below and shown on Fig. 1. Only those areas within 100 km of the proposed survey area are discussed below.

***Washington Islands National Wildlife Refuges*.—**The Washington Islands National Wildlife Refuges (NWRs) are located along 161 km of the outer coast of the Olympic Peninsula, encompassing more than 600 islands, sea stacks, rocks, and reefs. The area is comprised of three NWRs: Copalis NWR (47.13–47.48ºN), Quillayute Needles NWR (47.63–48.03ºN), and Flattery Rocks NWR (48.03–48.38ºN). The refuges do not include islands that are part of designated Native American reservations. Along much of the coastline adjacent to the islands lies the Olympic National Park (ONP). In 1970, all three of the Washington Islands NWRs were designated as Wilderness Areas, except for Destruction Island in Quillayute Needles NWR. As many as 500 Steller sea lions haul out and 150,000 pelagic birds nest annually on these islands (USFWS 2007). The OCNMS incorporates the entire area surrounding the islands and rocks of all three refuges (USFWS 2007). At its closest point, the Washington Islands NWR is ~30 km east of the nearest seismic transect (see Fig. 1). There are ~150 km of seismic transects within the sanctuary; 138 km are in intermediate water, and 12 km in deep water. No effort would occur in shallow water.

***Olympic Coast National Marine Sanctuary*.—**The OCNMS, designated in 1994, includes 8259 km^2 of marine waters off the Washington coast, extending 40–72 km seaward and covering much of the continental shelf and several major submarine canyons (NOAA 2011). The sanctuary protects a productive upwelling zone with high productivity and a diversity of marine life (NOAA 2011). This area also has numerous shipwrecks. The OCNMS management plan provides a framework for the sanctuary to manage potential threats to the sanctuary's marine resources under the *National Marine Sanctuaries Act*. Federal law provides national marine sanctuaries the authority to adopt regulations and issue permits for certain activities, including taking any marine mammal, sea turtle, or seabird in or above the sanctuary, except as authorized by the MMPA, the ESA, and the *Migratory Bird Treaty Act*. The easternmost portions of some seismic transects (totaling 150 km) would enter the OCNMS, and three OBSs are proposed to be deployed within the OCNMS, (Fig. 1). None of the transect lines within the OCNMS would occur in water <100 m deep.

Coastal Treaty Tribes (Hoh, Makah, Quileute, and Quinault) and the State of Washington also have responsibility for regulation of activities and management of marine resources within the boundaries of the OCNMS; therefore, OCNMS coordinates with them on regulatory jurisdiction over marine resources and activities within the boundaries of the Sanctuary. The OCNMS shares an overlapping boundary in the intertidal zone with the ONP. The ONP, designated in 1938, is a zone of exclusive federal jurisdiction encompassing 3734 km^2 and including some of the beaches and headlands along the coast (USFWS 2007). Approximately 75% of the coastal strip is in Congressionally designated wilderness, which is afforded additional protections under the *Wilderness Act*. The OCNMS is a partner in the management of the ONP marine resources.

***Lewis and Clark National Wildlife Refuge*.—**The Lewis and Clark NWR includes ~20 islands stretching over 43.5 km of the Columbia River, from the mouth upstream to nearly Skamakowa, WA (USFWS 2019). This refuge was established in 1972 to preserve the fish and wildlife habitat of the Columbia River estuary and supports large numbers of waterfowl, gulls, terns, wading birds, shorebirds, raptors, and songbirds. It is located ~60 km southeast of the closest seismic transect (see Fig. 1).

***Willapa National Wildlife Refuge*.—**The Willapa NWR is located within Willapa Bay and Columbia River, WA. It was established in 1973 by President Franklin D. Roosevelt to protect migrating birds and their habitat (USFWS 2013). It consists of multiple segments, with the nearest located ~43 km northeast of the closest seismic transect (see Fig. 1).

***Oregon Islands National Wildlife Refuge*.—**The Oregon Islands NWR (OINWR) spans 515 km of the Oregon coast from the Oregon/California border to Tillamook Head (~45.9°N) and includes all rocks and islands above the line of mean high tide, except for rocks and islands of the Three Arch Rocks NWR. All of the island acreage is designated National Wilderness, with the exception of Tillamook Rock (USFWS 2015). The OINWR is located ~2.3 km east of the nearest seismic transect (see Fig. 1).

***Three Arch Rocks National Wildlife Reserve*.—**Three Arch Rocks NWR consists of 60 m^2 on three large and six small rocky islands located ~1 km from shore. It is one of the smallest designated wilderness areas in the U.S. and is the only pupping site for the Steller sea lion in northern Oregon (USFWS 2016a). This NWR is located ~13 km southeast from the closest seismic transect (see Fig. 1).

***Washington State Seashore Conservation Area*.—**The Washington State Seashore Conservation Area includes all seashore between the line of ordinary high tide and the line of extreme low tide between Cape Disappointment (~46.3°N) and Griffiths Priday State Park (~47.1°N). The Conservation Area is under the jurisdiction of the Washington state parks and recreation commission (Washington State Parks n.d.). The Seashore Conservation Area is ~32 km east of the closest seismic transect (see Fig. 1).

***Cape Falcon Marine Reserve*.—**The Cape Falcon Marine Reserve combines a marine reserve and two marine protected areas (MPAs) located at ~45.7ºN, 124ºW. The entire protected area extends ~7 km along the coast of Oregon and out to ~7 km (see Fig. 1). The reserve and MPA portions are 32 km^2 and 20 km^2, respectively (ODFW 2019a). No animals or seaweed may be taken from the reserve (ODFW 2019a). The Cape Falcon Marine Reserve is located ~13.5 km east of the closest seismic transect (see Fig. 1).

***Cascade Head Marine Reserve*.—**This site includes a marine reserve surrounded by three MPAs and is located off the central Oregon coast at ~45°N, 124ºW. The entire protected area extends 16 km along the coast (see Fig. 1) and out to 5.6 km (ODFW 2019a), with total areas of 25.1 km^2 and 59.7 km^2 for the marine reserve and MPA portions, respectively. No animals or seaweed may be taken from the reserve (ODFW 2019a). Cascade Head Marine Reserve is located ~6 km east of the closest seismic transect (see Fig. 1).

***Otter Rock Marine Reserve*.—**The Otter Rock Marine Reserve encompasses 3 km^2 of nearshore rocky intertidal habitat at ~44.72–44.75°N (ODFW 2019a). No animals or seaweed may be taken from the reserve (ODFW 2019a). The reserve is located ~16 km east of the closest seismic transect (see Fig. 1).

***Cape Perpetua Marine Reserve*.—**This site combines a marine reserve, two MPAs, and a seabird protection area. It is located off the central coast of OR at ~44.2ºN, 124.1ºW. The entire protected area extends ~26.5 km along the coast (see Fig. 1) and out to ~5 km, with total areas of 37 km^2 and 49 km^2 for the reserve and MPA portions, respectively (ODFW 2019a). This marine reserve is located ~7 km east of the closest seismic transect (see Fig. 1).

***Redfish Rock Marine Reserve and Marine Protected Area*.—**The Redfish Rock Marine Reserve and MPA is located at ~42.67–44.70°N. The marine reserve encompasses 7 km^2 of nearshore water, and the adjacent MPA covers an additional ~13 km^2 (ODFW 2019a). Redfish Rock Marine Reserve is located 18 km east of the closest seismic transect (see Fig. 1).

3.2.4 Other Conservation Areas in Canada

Only those conservation areas within 100 km of the proposed survey area are discussed below. Race Rocks Ecological Reserve is located in the Strait of Juan de Fuca ~101 km from the nearest survey transect; it is currently under consideration for designation as an MPA and is an Area of Interest (AOI) (DFO 2017a). Hecate Strait/Queen Charlotte Sound Glass Sponge Reefs MPA is located 112 km from the nearest proposed seismic transect. There are several rockfish conservation areas (RCAs) adjacent to the proposed survey area; these are discussed in Section 3.6.5.

***Offshore Pacific Area of Interest/Proposed Offshore Pacific MPA*.—**The Offshore Pacific Area of Interest encompasses 139,700 km^2 of the Offshore Pacific Bioregion (OPB) west of Vancouver Island (DFO 2020a). It has unique seafloor features such as seamounts and hydrothermal vents and ecosystems that support the OPB. It includes the Offshore Pacific Seamounts and Vents Closure area, where all bottom contact from recreational and commercial fishing is prohibited, as well as other activities incompatible with the conservation of the ecological components. An advisory committee has been established for this AOI, and a management approach is being developed to move towards the protection of this area. The western-most seismic transects enter the AOI (see Fig. 1).

***Endeavour Hydrothermal Vents MPA*.—**The Endeavour Hydrothermal Vents (EHV) were designated as the first MPA under Canada's *Oceans Act* in 2003 (DFO 2018b). The EHV area covers 97 km^2 and is located on the Juan de Fuca Ridge, 256 km offshore from Vancouver Island, 2250 m below the ocean's surface (Tunnicliffe and Thompson 1999); it occurs within the AOI. Under the Canadian *Oceans Act*, underwater activities that may result in the disturbance, damage, destruction, or removal of the seabed, or any living marine organism or any part of its habitat, are prohibited in this MPA (Government of Canada 2021a). The EHV area is located ~84 km west of the closest seismic transect (see Fig. 1).

***Scott Islands Marine National Wildlife Area*.—**This area (11,546 km^2) was established in June 2018 under Canada's *Wildlife Act* and consists of the marine waters extending out from the northwestern tip of Vancouver Island and surrounding the five islands of the Scott Islands (Government of Canada 2021b). The Scott Islands support the greatest concentration of breeding seabirds on the Pacific coast of Canada, hosting over 1 million nesting seabirds a year, including tufted puffins, common murres, Cassin's auklets, and rhinoceros auklets (Government of Canada 2021b). It also attracts up to 10 million migratory birds annually, including short-tailed albatross, black-footed albatross, pink-footed shearwater, marbled murrelet, and ancient murrelet (Government of Canada 2021b). Pinniped rookeries are also located at the Scott Islands (Hoyt 2011), and the region encompasses a RCA. This National Wildlife Area is located ~30 km from the closest proposed seismic transect (see Fig. 1).

This area is also an Ecologically and Biologically Significant Area (EBSA) as determined by DFO due to its biologically rich environment, the diversity of marine mammals and fish, and it is important habitat for marine mammal species listed under SARA. In this National Wildlife Reserve, regulations prohibit any activity that is likely to disturb, damage, or destroy wildlife or its habitat. Among other restrictions, it is not permitted to be within 300 m of the low water mark of Triangle, Sartine, or Beresford islands, and vessels exceeding 400 t cannot anchor within 1 n.mi. of the aforementioned three islands (Government of Canada 2021c).

***Checleset Bay Ecological Reserve*.—**This ecological reserve is 346.5 km^2 and is located between Kyuquot and the Brooks Peninsula, off the northwest coast of Vancouver Island. It encompasses marine habitat for a reintroduced population of sea otters to increase their range and abundance; it also includes an RCA (B.C. Parks 2019). Fisheries restrictions are in effect in the reserve and research activities may be carried out but only under permit (B.C. Parks 2019). The Checleset Bay Ecological Reserve is located adjacent to the survey area (see Fig. 1).

***Pacific Rim National Park Reserve*.—**The marine component of this National Park Reserve covers 220.5 km^2 (Hoyt 2011). It is located in coastal and nearshore waters of southwestern Vancouver Island, including parts of Barkley Sound, and encompasses habitat for gray whales, in particular during the summer, as well as for numerous other marine species (Hoyt 2011). It is located 16 km east of the closest seismic transect. The National Park Reserve is partially located within the Clayoquot Sound UNESCO World Biosphere Reserve and includes several RCAs.

Clayoquot Sound UNESCO Biosphere Reserve encompasses a diverse range of ecosystems; it was designated in 2000 (UNESCO 2019). The marine component of Clayoquot Sound supports mudflats, beaches, and estuaries and contains the largest cover of eelgrass on the west coast of Vancouver Island. The marine area is important for gray whales, humpback whales, killer whales, and a variety of other marine mammal species.

***B.C. Northern Shelf MPA Network*.—**This initiative aims to build a network of MPAs for the shelf of B.C., stretching from the western shelf of northern Vancouver Island to Alaska (MPANetwork 2019), including the northern portion of the survey area. The Northern Shelf consists of diverse ecosystems that provides important habitat for a variety of species. The network is being developed by the Government of Canada, the Province of B.C., and First Nations.

***Ecologically and Biologically Significant Areas*.—**An EBSA is an area of relatively higher ecological or biological significance than surrounding areas (Rubridge et al. 2018). The scientific criteria to identify an EBSA have been established at the national level by DFO (2004a) and at the international level by the Convention on Biological Diversity (CBD 2008). The identification of an EBSA does not imply specific protection, rather it is a means of recognizing the special features within the area and the management of activities within the area are required to exhibit greater risk aversion (Ban et al. 2016). In order for an area to be protected under the *National Marine Conservation Areas Act* or be designated as an MPA in Canada, it must first be identified as an EBSA, and the societal values and potential threats must be identified, in addition to the implementation of a management plan (Ban et al. 2016). There are five EBSAs within the survey area and two EBSAs adjacent to the survey area (Fig. 2; Table 4).

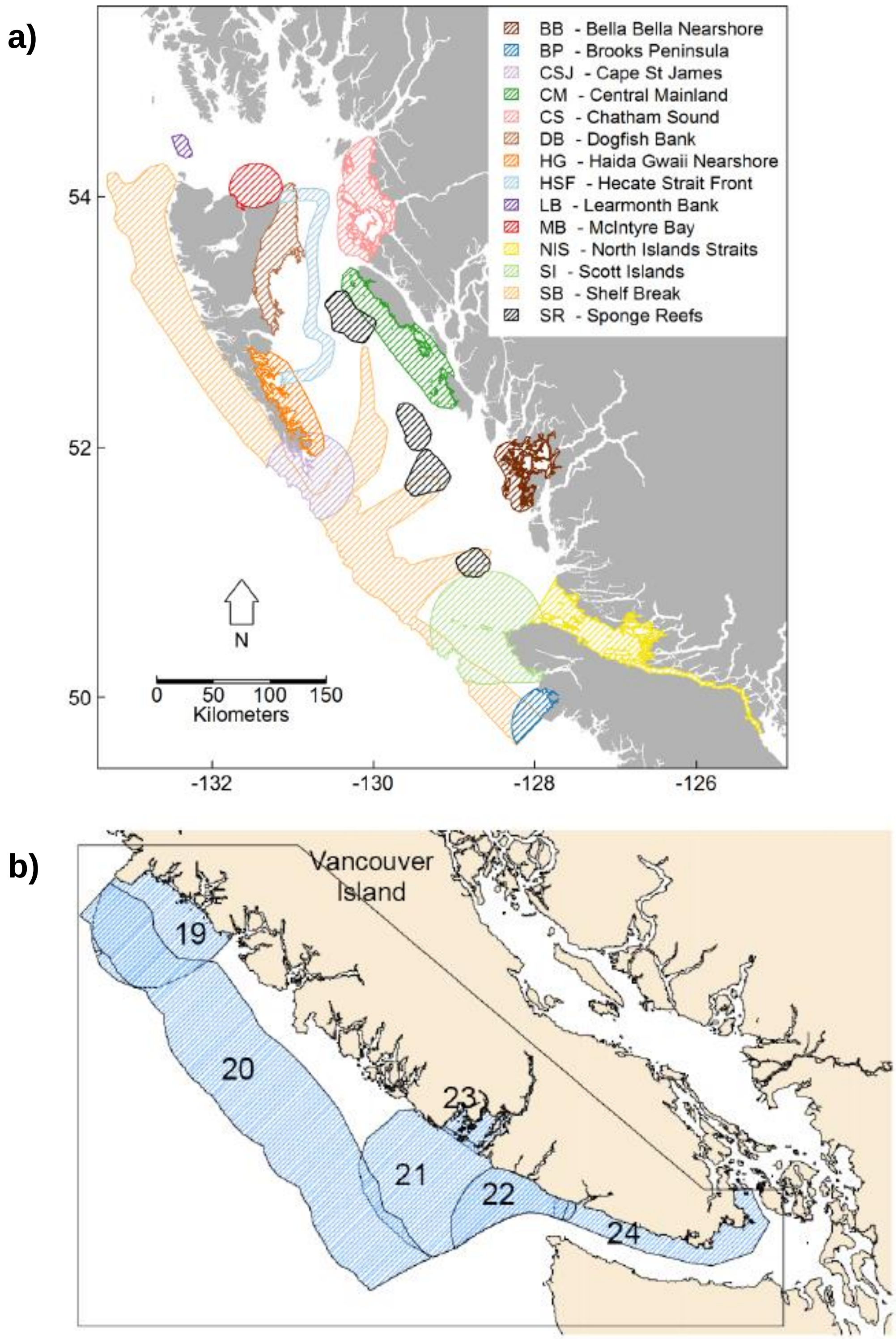

FIGURE 2. EBSAs off the B.C. coast in (a) the Pacific Northern Shelf Bioregion (Source: Rubidge et al. 2018) and (b) the Southern Shelf Bioregion (Source: DFO 2013b; 19 = Brooks Peninsula; 20 = Shelf Break; 21 = Continental Shelf Off Of Barkley Sound; 22 = Juan de Fuca Eddy; 23 = Barkley Sound and Alberni Inlet; 24 = Strait of Juan de Fuca).

TABLE 4. Summary of the Ecologically or Biologically Significant Marine Areas (a) within Canadian waters of the proposed survey area, and (b) adjacent to the proposed survey area.

(a)

EBSA	Location	Significance	References
Scott Islands (SI)	Archipelago of five islands (Lanz, Cox, Sartine, Beresford, Triangle Island) located off the northwestern point of Vancouver Island, ~10 km off Cape Scott Provincial Park	• Area of significant upwelling and tidal mixing • High plankton productivity Important Species: • Spawning, breeding, or rearing: Pacific cod, lingcod, sablefish, arrowtooth flounder, Petrale sole, butter sole, rock sole, dover sole, English sole, widow rockfish, Steller sea lion, Cassin's auklet, rhinoceros auklet, tufted puffin, common murre, cormorants, pigeon guillemot, storm petrel, glaucous winged gull • Feeding: Pacific hake, Pacific herring, gray whale, northern fur seal • Aggregation: humpback whale, sea otter	Clarke and Jamieson (2006); DFO (2013b); Ban et al. (2016); Rubidge et al. (2018)
Brooks Peninsula (BI)	West coast of Vancouver Island. Brooks Peninsula juts 20 km into the Pacific Ocean and is home to a Provincial Park	• High diversity of breeding and migrating bird species • High plankton productivity • Bottleneck between Brooks Peninsula and the Southern Shelf Break Important Species: • Spawning, rearing, or breeding: lingcod, common murre, tufted puffin, glaucous-winged gull, rhinoceros auklet • Aggregation: sea otter • Migration: possibly green sturgeon	DFO (2013b); Ban et al. (2016); Rubidge et al. (2018)
Southern Shelf Break (SSB)	West coast of Vancouver Island from the Brooks Peninsula down to Barkley Sound along the shelf	• High productivity and aggregation of plankton • Site of strong trophic transfers Important Species: • Spawning, rearing, or breeding: sablefish, dover sole, rockfish • Feeding: humpback whale, hake, northern fur seal • Aggregation: sperm, fin, blue, and sei whale; coral; tanner crab; possibly leatherback turtle	DFO (2013b); Ban et al. (2016)
Continental Shelf off Barkley Sound	West coast of Vancouver Island that forms the entrance Alberni Inlet	• High productivity and aggregation of plankton • Submarine banks, convergent circulation, and shallow depths • High trophic transfer Important Species: • Spawning, rearing, or breeding: Pacific herring, Pacific cod, sand lance • Feeding: humpback whale, southern resident killer whale, porpoise, northern fur seal, Steller sea lion, Pacific sardine, Pacific hake, candlefish • Aggregation: green sturgeon, dungeness crab, shrimp • Migration: Pacific sardine, candlefish, gray whale	DFO (2013b)
Juan de Fuca Eddy	West coast of Vancouver Island and to the northwest coast of the Olympic Peninsula, WA	• Geographical bottleneck Important Species: • Spawning, rearing, or breeding: Pacific herring • Feeding: gray whale, Pacific salmon • Aggregation: harbor porpoise, Dover sole, Pacific hake, green sea urchin • Migration: Pacific salmon, Pacific herring, candlefish	DFO (2013b)

(b)

EBSA	Location	Significance	References
Barkley Sound and Alberni Inlet	West coast of Vancouver Island that forms the entrance to Alberni Inlet	• Geographical bottleneck Important Species: • Spawning, rearing, or breeding: Pacific herring, juvenile eulachon, flatfish, gull, pelagic cormorant, • Feeding: gray whale, humpback whale, harbor seal, Steeler sea lion, salmon, sardine, surf scoter • Aggregation: Pacific loon, pigeon guillemot, marbles murrelets, Olympia oyster, Pacific oyster • Migration: green sturgeon, Pacific salmon • Uniqueness: Pacific hake (resident) inshore stock, historical basking shark records	DFO (2013b)
Juan de Fuca Strait	West coast of Vancouver Island and to the northwest coast of the Olympic Peninsula of Washington	• Geographical bottleneck Important Species: • Spawning, rearing, or breeding: Pacific herring • Feeding: gray whale, Pacific salmon • Aggregation: harbor porpoise, Dover sole, Pacific hake, green sea urchin, dungeness crab • Migration: Pacific salmon, eulachon • Uniqueness: killer whale critical habitat	DFO (2013b)

3.3 Marine Mammals

Thirty-three marine mammal species could occur in or near the proposed survey area, including 7 mysticetes (baleen whales), 19 odontocetes (toothed whales), 6 pinnipeds (seals and sea lions), and the northern sea otter (Table 5). Seven of the species are listed under the U.S. ESA as ***endangered***, including the sperm, humpback (Central America DPS), sei, fin, blue, North Pacific right, and Southern Resident DPS of killer whales. The ***threatened*** Mexico DPS of the humpback whale and the ***threatened*** Guadalupe fur seal could also occur in the proposed survey area. It is very unlikely that gray whales from the ***endangered*** Western North Pacific DPS would occur in the proposed survey area. The long-beaked common dolphin (*D. capensis*) and rough-toothed dolphin (*Steno bredanensis*) are distributed farther to the south. These species are unlikely to be seen in the proposed survey area and are not addressed in the summaries below. Although no sightings of *D. capensis* have been made off Oregon/Washington, Ford (2005) reported seven confirmed *D. capensis* sightings in B.C. waters from 1993–2003. All records occurred in inshore waters; Ford (2005) described *D. capensis* as a “rare visitor” to B.C. waters, more likely to occur during warm-water periods. No other sightings have been made since 2003 (Ford 2014).

General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of marine mammals are given in § 3.6.1, § 3.7.1, § 3.8.1, and § 3.8.1 of the PEIS. One of the qualitative analysis areas (QAAs) defined in the PEIS, the B.C. Coast, is located just to the north of the proposed survey area. The general distribution of mysticetes, odontocetes, pinnipeds, and sea otters off the B.C. Coast is discussed in § 3.6.3.2, § 3.7.3.2, § 3.8.3.2, and § 3.9.3.1 of the PEIS, respectively. Southern California was chosen as a detailed analysis area (DAA) in the PEIS. The general distribution of mysticetes, odontocetes, pinnipeds, and sea otters in southern California is discussed in § 3.6.2.3, § 3.7.2.3, § 3.8.2.3, and § 3.9.2.2 of the PEIS, respectively. The rest of this section deals specifically with species distribution in the proposed survey area. Although Harvey et al. (2007) and Best et al. (2015) provide information on densities and marine mammal hotspots in B.C. waters, their survey areas do not cover the proposed study area.

TABLE 5. The habitat, abundance, and conservation status of marine mammals that could occur in or near the proposed seismic survey area in the Northeast Pacific Ocean. N.A. means not available.

Species	**Occurrence in Area**[1]	**Habitat**	**Abundance**[2]	**U.S. *ESA***[3]	**Canada**		**IUCN**[6]	**CITES**[7]
					COSEWIC[4]	**SARA**[5]		
Mysticetes								
North Pacific right whale	Rare	Coastal, shelf, offshore	400-500[8]	EN	EN	EN	CR[9]	I
Gray whale	Common	Coastal, shelf	232[10]; 26,960	DL[11]	EN[12]	NS	LC[13]	I
Humpback whale	Common	Mainly nearshore and banks	2,900; 10,103[14]	EN/T[15]	SC	SC	LC	I
Common minke whale	Uncommon	Nearshore, offshore	636; 20,000[16]	NL	NAR	NS	LC	I
Sei whale	Rare	Mostly pelagic	519; 27,197[17]	EN	EN	EN	EN	I
Fin whale	Common	Slope, pelagic	9,029; 13,620-18,680[18]	EN	SC	T	VU	I
Blue whale	Rare	Pelagic and coastal	1,496[19]	EN	EN	EN	EN	I
Odontocetes								
Sperm whale	Common	Pelagic, steep topography	1,997; 26,300[20]	EN	NAR	NS	VU	I
Pygmy sperm whale	Rare	Deep, off shelf	4111	NL	NAR	NS	DD	II
Dwarf sperm whale	Rare	Deep, shelf, slope	N.A.	NL	NS	NS	DD	II
Cuvier's beaked whale	Uncommon	Pelagic	3,274	NL	NAR	NS	LC	II
Baird's beaked whale	Uncommon	Pelagic	2,697	NL	NAR	NS	DD	I
Blainville's beaked whale	Rare	Pelagic	3,044[21]	NL	NAR	NS	DD	II
Hubbs' beaked whale	Rare	Slope, offshore	3,044[21]	NL	NAR	NS	DD	II
Stejneger's beaked whale	Uncommon	Slope, offshore	3,044[21]	NL	NAR	NS	DD	II
Common bottlenose dolphin	Rare	Coastal, shelf, deep	1,924[22]	NL	NAR	NS	LC	II
Striped dolphin	Rare	Off continental shelf	29,211	NL	NAR	NS	LC	II
Short-beaked common dolphin	Uncommon	Shelf, pelagic, seamounts	969,861	NL	NAR	NS	LC	II
Pacific white-sided dolphin	Common	Offshore, slope	26,814 22,160[41]	NL	NAR	NS	LC	II
Northern right whale dolphin	Common	Slope, offshore waters	26,556	NL	NAR	NS	LC	II
Risso's dolphin	Uncommon	Shelf, slope, seamounts	6,336	NL	NAR	NS	LC	II
False killer whale	Rare	Pelagic	N.A.	NL	NAR	NS	NT	II
Killer whale	Common	Widely distributed	75[23] 243[24] 302[25] 300[26]	EN[27]	EN/T[28]	EN/T[28]	DD	II
Short-finned pilot whale	Rare	Pelagic, high-relief	836	NL	NAR	NS	LC	II
Harbor porpoise	Common	Shelf	21,487[29]; 24,195[30] 8,091[41]	NL	SC	SC	LC	II
Dall's porpoise	Common	Shelf, slope, offshore	25,750 5,303[41]	NL	NAR	NS	LC	II
Pinnipeds								
Guadalupe fur seal	Rare	Mainly coastal, pelagic	34,187	T	NAR	NS	LC	I

Species	Occurrence in Area[1]	Habitat	Abund-ance[2]	U.S. *ESA*[3]	Canada		IUCN[6]	CITES[7]
					COSEWIC[4]	SARA[5]		
Northern fur seal	Uncommon	Pelagic, offshore	14,050[31] 620,660[32]	NL	T	NS	VU	N.A.
Northern elephant seal	Uncommon	Coastal, pelagic in migration	179,000[33]	NL	NAR	NS	LC	N.A.
Harbor seal	Common	Coastal	24,732[34] 105,000[42]	NL	NAR	NS	LC	N.A.
Steller sea lion	Common	Coastal, offshore	77,149[35] 4,037[41]	DL[36]	SC	SC	NT[37]	N.A.
California sea lion	Uncommon	Coastal	257,606[38]	NL	NAR	NS	LC	N.A.
Fissipeds								
Northern Sea Otter	Rare	Coastal	2,058[39] 6,754[43] 2,928[44]	NL[40]	SC	SC	EN	II

[1] Occurrence in area at the time of the survey; based on professional opinion and available data.
[2] Abundance for Eastern North Pacific, U.S., or CA/OR/WA stock from Carretta et al. (2020), unless otherwise stated.
[3] U.S. *Endangered Species Act* (ESA; NOAA 2019d): EN = Endangered, T = Threatened, NL = Not listed.
[4] Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status (Government of Canada 2021); EN = Endangered; T = Threatened; SC = Special Concern; NAR = Not at Risk.
[5] Pacific Population for Canada's *Species at Risk Act* (SARA) Schedule 1 species, unless otherwise noted (Government of Canada 2021d); EN = endangered; T = Threatened; SC = Special Concern; NS = No Status.
[6] Classification from the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2019); CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient.
[7] Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES; UNEP-WCMC 2017): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.
[8] North Pacific (Jefferson et al. 2015).
[9] The Northeast Pacific subpopulation is critically endangered; globally, the North Pacific right whale is endangered.
[10] Pacific Coast Feeding Group (Calambokidis et al. 2019).
[11] Although the Eastern North Pacific DPS was delisted under the ESA, the Western North Pacific DPS is listed as endangered.
[12] Pacific Coast Feeding Aggregation and Western Pacific populations are listed as endangered; the Northern Pacific Migratory population is not at risk.
[13] Globally considered as least concern; western population listed as endangered.
[14] Central North Pacific stock (Muto et al. 2020).
[15] The Central America DPS is endangered, and the Mexico DPS is threatened; the Hawaii DPS was delisted in 2016 (81 FR 62260, 8 September 2016).
[16] Northwest Pacific and Okhotsk Sea (IWC 2018).
[17] Central and Eastern North Pacific (Hakamada and Matsuoka 2015a).
[18] North Pacific (Ohsumi and Wada 1974).
[19] Eastern North Pacific Stock (Calambokidis and Barlow 2013).
[20] Eastern Temperate Pacific; estimate based on visual sightings (Barlow and Taylor 2005).
[21] All mesoplodont whales (Moore and Barlow 2017; Carretta et al. 2020).
[22] California/Oregon//Washington offshore stock (Carretta et al. 2020).
[23] Southern Resident stock (OrcaNetwork 2021).
[24] West Coast Transient stock; minimum estimate (Muto et al. 2020).
[25] Northern Resident stock (Muto et al. 2020).
[26] North Pacific Offshore stock (Carretta et al. 2020).
[27] The Southern Resident DPS is listed as endangered; no other stocks are listed.
[28] Southern resident population is as endangered; the northern resident, offshore, and transient populations are threatened.
[29] Northern Oregon/southern Washington stock (Carretta et al. 2020).
[30] Northern California/Southern Oregon stock (Carretta et al. 2020).
[31] California stock (Carretta et al. 2020).
[32] Eastern Pacific stock (Muto et al. 2020).
[33] California breeding stock (Carretta et al. 2020).
[34] Oregon and Washington Coast stock; estimate >8 years old (Carretta et al. 2020).
[35] Estimate for entire Eastern stock (Muto et al. 2020).
[36] The Eastern DPS was delisted in 2013 (78 FR 66139, 4 November 2013); the Western DPS is listed as endangered.
[37] Globally considered as near threatened; western population listed as endangered.
[38] U.S. stock (Carretta et al. 2020).
[39] Washington (Jeffries et al. 2019).
[40] Southwest Alaska DPS is listed as threatened.
[41] Coastal waters of B.C. (Best et al. 2015).
[42] B.C. (Ford 2014).
[43] B.C. (Nichol et al. 2015).
[44] USFWS (2021).

3.3.1 Mysticetes

3.3.1.1 North Pacific Right Whale *(Eubalaena japonica)*

North Pacific right whales summer in the northern North Pacific, primarily in the Okhotsk Sea (Brownell et al. 2001) and in the Bering Sea (Shelden et al. 2005; Wade et al. 2006). This species is divided into western and eastern North Pacific stocks. The eastern North Pacific stock that occurs in U.S. waters numbers only ~31 individuals (Wade et al. 2011a), and critical habitat has been designated in the eastern Bering Sea and in the Gulf of Alaska, south of Kodiak Island (NOAA 2019c). Wintering and breeding areas are unknown, but have been suggested to include the Hawaiian Islands, Ryukyu Islands, and Sea of Japan (Allen 1942; Banfield 1974; Gilmore 1978; Reeves et al. 1978; Herman et al. 1980; Omura 1986).

Whaling records indicate that right whales once ranged across the entire North Pacific north of 35ºN and occasionally occurred as far south as 20ºN (Kenney 2018). Although right whales were historically reported off the coast of Oregon, occasionally in large numbers (Scammon 1874; Rice and Fiscus 1968), extensive shore-based and pelagic commercial whaling operations never took large numbers of the species south of Vancouver Island (Rowlett et al. 1994). Nonetheless, Gilmore (1956) proposed that the main wintering ground for North Pacific right whales was off the Oregon coast and possibly northern California, postulating that the inherent inclement weather in those areas discouraged winter whaling (Rice and Fiscus 1968).

Since the 1960s, North Pacific right whale sightings have been relatively rare (e.g., Clapham et al. 2004; Shelden et al. 2005). However, starting in 1996, right whales have been seen regularly in the southeast Bering Sea, including calves in some years (Goddard and Rugh 1998; LeDuc et al. 2001; Moore et al. 2000, 2002a; Wade et al. 2006; Zerbini et al. 2009); they have also been detected acoustically (McDonald and Moore 2002; Munger et al. 2003; 2005, 2008; Berchok et al. 2009). They are known to occur in the Bering Sea from May–December (e.g., Tynan et al. 2001; Hildebrand and Munger 2005; Munger et al. 2005, 2008). In March 1979, a group of four right whales was seen in Yakutat Bay (Waite et al. 2003), but there were no further reports of right whale sightings in the Gulf of Alaska until July 1998, when a single whale was seen southeast of Kodiak Island (Waite et al. 2003). Since 2000, several other sightings and acoustic detections have been made in the western Gulf of Alaska during summer (Waite et al. 2003; Mellinger et al. 2004; RPS 2011; Wade et al. 2011a,b; Rone et al. 2014). A biologically important area (BIA) for feeding for North Pacific right whales was designated east of the Kodiak Archipelago, encompassing the Gulf of Alaska critical habitat and extending south of 56°N and north of 58°N and beyond the shelf edge (Ferguson et al. 2015).

South of 50ºN in the eastern North Pacific, only 29 reliable sightings were recorded from 1900–1994 (Scarff 1986, 1991; Carretta et al. 1994). Despite many miles of systematic aerial and ship-based surveys for marine mammals off the coasts of California/Oregon/Washington over the years, only seven documented sightings of right whales were made from 1990–2000 (Waite et al. 2003). Two North Pacific right whale calls were detected on a bottom-mounted hydrophone (located in water 1390 m deep) off the Washington coast on 29 June 2013 (Širović et al. 2014).

Right whales have been scarce in B.C. since 1900 (Ford 2014). In the 1900s, there were only six records of right whales for B.C., all of which were catches by whalers (Ford et al. 2016). Since 1951, there have only been three confirmed records. A sighting of one individual 15 km off the west coast of Haida Gwaii was made on 9 June 2013 and another sighting occurred on 25 October 2013 on Swiftsure Bank near the entrance to the Strait of Juan de Fuca (Ford 2014; Ford et al. 2016; DFO 2017b). The third and most recent sighting was made off Haida Gwaii in June 2018 (CBC 2018a). There have been two additional unconfirmed records for B.C., including one off Haida Gwaii in 1970 and another for the Strait of Juan de Fuca in 1983 (Brownell et al. 2001; DFO 2011a; Ford 2014).

Based on the very low abundance of this species, its rarity off the coasts of B.C., Washington, and Oregon in recent decades, and the likelihood that animals would be feeding in the Bering Sea and Gulf of Alaska at the time of the survey, it is possible although very unlikely that a North Pacific right whale could be encountered in the proposed survey area during the period of operations.

3.3.1.2 Gray Whale (*Eschrichtius robustus*)

Two separate populations of gray whales have been recognized in the North Pacific: the eastern North Pacific and western North Pacific (or Korean-Okhotsk) stocks (LeDuc et al. 2002; Weller et al. 2013). However, the distinction between these two populations has been recently debated owing to evidence that whales from the western feeding area also travel to breeding areas in the eastern North Pacific (Weller et al. 2012, 2013; Mate et al. 2015). Thus, it is possible that whales from either the U.S. ESA-listed ***endangered*** Western North Pacific DPS or the delisted Eastern North Pacific DPS could occur in the proposed survey area, although it is unlikely that a gray whale from the Western North Pacific DPS would be encountered during the time of the survey. Gray whale populations were severely reduced by whaling, and the western population has remained highly depleted, but the eastern North Pacific population is considered to have recovered. In 2009, Punt and Wade (2012) estimated that the eastern North Pacific population was at 85% of its carrying capacity of 25,808 individuals.

The eastern North Pacific gray whale breeds and winters in Baja California, and migrates north to summer feeding grounds in the northern Bering Sea, Chukchi Sea, and western Beaufort Sea (Rice and Wolman 1971; Rice 1998; Jefferson et al. 2015). The migration northward occurs from late February–June (Rice and Wolman 1971), with a peak into the Gulf of Alaska during mid-April (Braham 1984). Instead of migrating to arctic and sub-arctic waters, some individuals spend the summer months scattered along the coast from California to Southeast Alaska (Rice and Wolman 1971; Nerini 1984; Darling et al. 1998; Calambokidis and Quan 1999; Dunham and Duffus 2001, 2002; Calambokidis et al. 2002, 2015, 2017). There is genetic evidence indicating the existence of this Pacific Coast Feeding Group (PCFG) as a distinct local subpopulation (Frasier et al. 2011; Lang et al. 2014), and the U.S. and Canada recognize it as such (COSEWIC 2017; Carretta et al. 2019). However, the status of the PCFG as a separate stock is currently unresolved (Weller et al. 2013). For the purposes of abundance estimates, the PCFG is defined as occurring between 41°N to 52°N from 1 June to 30 November (IWC 2012). The 2017 abundance estimate for the PCFG was 232 whales (Calambokidis et al. 2019); ~100 of those may occur in B.C. during summer (Ford 2014). In B.C., most summer resident gray whales are found in Clayoquot Sound, Barkley Sound, and along the southwestern shore of Vancouver Island, and near Cape Caution, on the mainland (Ford 2014). During surveys in B.C. waters during summer, most sightings were made within 10 km from shore in water shallower than 100 m (Ford et al. 2010a).

BIAs for feeding gray whales along the coasts of Washington, Oregon, and California have been identified, including northern Puget Sound, Northwestern Washington, and Grays Harbor (WA); Depoe Bay and Cape Blanco & Orford Reef (OR), and Point St. George (CA); most of these areas are of importance from late spring through early fall (Calambokidis et al. 2015). Resident gray whales have been observed foraging off the coast of Oregon from May–October (Newell and Cowles 2006) and off Washington from June through November (Scordino et al. 2014). A least 28 gray whales were observed near Depoe Bay, OR (~44.8°N), for three successive summers (Newell and Cowles 2006). BIAs have also been identified for migrating gray whales along the entire coasts of Washington, Oregon, and California; although most whales travel within 10 km from shore, the BIAs were extended out to 47 km from the coastline (Calambokidis et al. 2015). Gray whales from the far north begin to migrate south to breeding grounds on the west coast of Baja California and the southeastern Gulf of California in October and November (Braham 1984; Rugh et al. 2001). Gray whales migrate closest to the Washington/Oregon coastline during spring (April–June), when most strandings are observed (Norman et al. 2004).

Oleson et al. (2009) observed 116 gray whales off the outer Washington coast (~47ºN) during 42 small boat surveys from August 2004 through September 2008; mean distances from shore during the southern migration (December–January), northern migration (February–April), and summer feeding (May–October) activities were 29, 9, and 12 km, respectively; mean bottom depths during these activities were 126, 26, and 33 m, respectively. Ortega-Ortiz and Mate (2008) tracked the distribution and movement patterns of gray whales off Yaquina Head on the central Oregon coast (~44.7°N) during the southbound and northbound migration in 2008. The average distance from shore to tracked whales ranged from 200 m to 13.6 km; average bottom depth of whale locations was 12–75 m. The migration paths of tracked whales seemed to follow a constant depth rather than the shoreline. During aerial surveys over the shelf and slope off Oregon and Washington, gray whales were seen during the months of January, June–July, and September; one sighting was made off the Columbia River estuary in water >200 m during June 2011 (Adams et al. 2014). Two sightings of three whales were seen from R/V *Northern Light* during a survey off southern Washington in July 2012 (RPS 2012a).

In B.C., gray whales are common off Haida Gwaii and western Vancouver Island (Williams and Thomas 2007), in particular during migration. Whales travel southbound along the coast of B.C. during their migration to Baja California between November and January, with a peak off Vancouver Island during late December; during the northbound migration, whales start appearing off Vancouver Island during late February, with a peak in late March, with fewer whales occurring during April and May (Ford 2014). Northbound migrants typically travel within ~5 km from shore (Ford 2014), although some individuals have been sighted more than 10 km from shore (Ford et al. 2010a, 2013). Based on acoustic detections described by Meyer (2017 *in* COSEWIC 2017), the southward migration also takes place in shallow shelf waters. After leaving the waters off Vancouver Island, gray whales typically use Hecate Strait and Dixon Entrance as opposed to the west coast of Haida Gwaii as their main migratory corridor through Southeast Alaska during the northbound migration (Ford et al. 2013); during the southbound migration, gray whales likely migrate past the outer coast of Haida Gwaii (Ford 2014; Mate et al. 2015; COSEWIC 2017).

The proposed surveys would occur during the late spring/summer feeding season, when most individuals from the eastern North Pacific stock occur farther north. However, some migrating gray whales could occur within the nearshore waters of the survey area. All transect lines off Washington are located at least 21 km from shore, and at least 9.5 km off Oregon. As most whales are likely to occur closer to shore when migrating, gray whales are unlikely to be encountered within the survey area; nonetheless, the airgun array would be shut down if a gray whale mother-calf pair were sighted during operations. In addition to migrating whales, individuals from the PCFG could be encountered in nearshore waters of the proposed project area, although few are expected to be seen more than 10 km from shore.

In 2019, NOAA declared an unusual mortality event (UME) for gray whales, as an elevated number of strandings have occurred along the coast of the Pacific Northwest since January 2019 (NOAA 2021a). As of 8 March 2021, a total of 418 stranded gray whales have been reported, including 203 in the U.S. (48 in Washington; 9 in Oregon), 199 in Mexico, and 16 in B.C.; some of the whales were emaciated (NOAA 2021a). A UME for gray whales was also declared in 1999–2000 (NOAA 2021a).

3.3.1.3 Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found throughout all oceans of the World (Clapham 2018). Based on genetic data, there could be three subspecies, occurring in the North Pacific, North Atlantic, and Southern Hemisphere (Jackson et al. 2014). Nonetheless, genetic analyses suggest some gene flow (either past or present) between the North and South Pacific (e.g., Jackson et al. 2014; Bettridge et al. 2015). Although considered to be mainly a coastal species, humpback whales often traverse deep pelagic areas while migrating (Calambokidis et al. 2001; Garrigue et al. 2002, 2015; Zerbini et al. 2011). Humpbacks migrate between summer feeding grounds in high latitudes and winter calving and breeding grounds in tropical waters (Clapham and Mead 1999).

North Pacific humpback whales summer in feeding grounds along the Pacific Rim and in the Bering and Okhotsk seas (Pike and MacAskie 1969; Rice 1978; Winn and Reichley 1985; Calambokidis et al. 2000, 2001, 2008; Bettridge et al. 2015). Humpbacks winter in four different breeding areas: (1) the coast of Mexico; (2) the coast of Central America; (3) around the main Hawaiian Islands; and (4) in the western Pacific, particularly around the Ogasawara and Ryukyu islands in southern Japan and the northern Philippines (Calambokidis et al. 2008; Bettridge et al. 2015). These breeding areas are recognized as the Mexico, Central America, Hawaii, and Western Pacific DPSs, but feeding areas have no DPS status (Bettridge et al. 2015; NMFS 2016b). There is potential for mixing of the western and eastern North Pacific humpback populations on their summer feeding grounds, but several sources suggest that this occurs to a limited extent (Muto et al. 2019). NMFS is currently reviewing the global humpback whale stock structure in light of the revisions to their ESA listing and identification of 14 DPSs (NMFS 2016b). Individuals from the Hawaii, Mexico, and Central America DPSs could occur in the proposed survey area. According to Wade (2017), off southern B.C. and Washington, ~63.5%, 27.9%, and 8.7% are from the Hawaii, Mexico, and Central America DPSs, respectively; off Oregon and California, the majority are from the Central America DPS (67.2%), with 32.7% from the Mexico DPS, and none from the Hawaii DPS.

During summer, most eastern North Pacific humpback whales are on feeding grounds in Alaska, with smaller numbers summering off the U.S. west coast and B.C. (Calambokidis et al. 2001, 2008). Individuals encountered in the proposed survey area would be from the Hawaii, Mexico, and/or Central America DPSs (Calambokidis et al. 2008; Ford 2014). The humpback whale is the most common species of large cetacean reported off the coasts of Oregon and Washington from May–November (Green et al. 1992; Calambokidis et al. 2000, 2004). The highest numbers have been reported off Oregon during May and June and off Washington during July–September. Humpbacks occur primarily over the continental shelf and slope during the summer, with few reported in offshore pelagic waters (Green et al. 1992; Calambokidis et al. 2004, 2015; Becker et al. 2012; Barlow 2016). BIAs for feeding humpback whales along the coasts of Oregon and Washington, which have been designated from May–November, are all within ~80 km from shore, and include the waters off northern Washington, and Stonewall and Heceta Bank, OR; another five BIAs occur off California (Calambokidis et al. 2015). Six humpback whale sightings (8 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey. There were 98 humpback whale sightings (213 animals) made during the July 2012 L-DEO seismic survey off southern Washington (RPS 2012a), and 11 sightings (23 animals) during the July 2012 L-DEO seismic survey off Oregon (RPS 2012c).

Humpback whales are common in the waters of B.C., where they occur in inshore, outer coastal, continental shelf waters, as well as offshore (Ford 2014). Williams and Thomas (2007) estimated an abundance of 1310 humpback whales in inshore coastal waters of B.C. based on surveys conducted in 2004 and 2005. Best et al. (2015) provided an estimate of 1029 humpbacks based on surveys during 2004–2008.

In B.C., humpbacks are typically seen within 20 km from the coast, in water <500 m deep (Ford et al. 2010a). They were the most frequently sighted cetacean during DFO surveys in 2002–2008 (Ford et al. 2010a). Critical habitat for humpbacks has been designated in B.C., including the waters of the proposed survey area off southwestern Vancouver Island (DFO 2013a). Humpback whales were detected acoustically on La Pérouse Bank off southwestern Vancouver Island from May through September 2007 (Ford et al. 2010b).

The greatest numbers are seen in B.C. between April and November, although humpbacks are known to occur there throughout the year (Ford et al. 2010a; Ford 2014). Gregr et al. (2000) also presented evidence of widespread winter foraging in B.C. based on whaling records. Humpback whales are thought to belong to at least two distinct feeding stocks in B.C.; those identified off southern B.C. show little interchange with those seen off northern B.C. (Calambokidis et al. 2001, 2008). Humpback whales identified in southern B.C. show a low level of interchange with those seen off California/Oregon/ Washington (Calambokidis et al. 2001). Humpback whales are likely to be common in the proposed survey area, especially in nearshore waters.

3.3.1.4 Common Minke Whale (*Balaenoptera acutorostrata scammoni*)

The minke whale has a cosmopolitan distribution that spans from tropical to polar regions in both hemispheres (Jefferson et al. 2015). In the Northern Hemisphere, the minke whale is usually seen in coastal areas, but can also be seen in pelagic waters during its northward migration in spring and summer and southward migration in autumn (Stewart and Leatherwood 1985). In the North Pacific, the summer range of the minke whale extends to the Chukchi Sea; in the winter, the whales move south to within 2º of the Equator (Perrin et al. 2018).

The International Whaling Commission (IWC) recognizes three stocks of minke whales in the North Pacific: the Sea of Japan/East China Sea, the rest of the western Pacific west of 180ºN, and the remainder of the Pacific (Donovan 1991). Minke whales are relatively common in the Bering and Chukchi seas and in the Gulf of Alaska but are not considered abundant in any other part of the eastern Pacific (Brueggeman et al. 1990). In the far north, minke whales are thought to be migratory, but they are believed to be year-round residents in nearshore waters off west coast of the U.S. (Dorsey et al. 1990).

Sightings have been made off Oregon and Washington in shelf and deeper waters (Green et al. 1992; Adams et al. 2014; Barlow 2016; Carretta et al. 2019). An estimated abundance of 211 minke whales was reported for the Oregon/Washington region based on sightings data from 1991–2005 (Barlow and Forney 2007), whereas a 2008 survey did not record any minke whales while on survey effort (Barlow 2010). The abundance for Oregon/Washington for 2014 was estimated at 507 minke whales (Barlow 2016). There were no sightings of minke whales off Oregon/Washington during the June–July 2012 L-DEO Juan de Fuca plate seismic survey or during the July 2012 L-DEO seismic survey off Oregon (RPS 2012b,c). One minke whale was seen during the July 2012 L-DEO seismic survey off southern Washington (RPS 2012a).

Minke whales are sighted regularly in nearshore waters of B.C., but they are not abundant (COSEWIC 2006). They are most frequently sighted around the Gulf Islands and off northeastern Vancouver Island (Ford 2014). They are also regularly seen off the east coast of Moresby Island, and in Dixon Entrance, Hecate Strait, Queen Charlotte Sound, and the west coast of Vancouver Island where they occur in shallow and deeper water (Ford et al. 2010a; Ford 2014). Williams and Thomas (2007) estimated minke whale abundance for inshore coastal waters of B.C. at 388 individuals based on surveys conducted in 2004 and 2005. Best et al. (2015) provided an estimate of 522 minke whales based on surveys during 2004–2008. Most sightings have been made during July and August; although most minke whales are likely to migrate south during the winter, they can be seen in B.C. waters throughout the year; however, few sightings occur from December through February (Ford 2014). Minke whales are expected to be uncommon in the proposed survey area.

3.3.1.5 Sei Whale (*Balaenoptera borealis*)

The sei whale occurs in all ocean basins (Horwood 2018) but appears to prefer mid-latitude temperate waters (Jefferson et al. 2015). It undertakes seasonal migrations to feed in subpolar latitudes during summer and returns to lower latitudes during winter to calve (Horwood 2018). The sei whale is pelagic and generally not found in coastal waters (Harwood and Wilson 2001). It occurs in deeper waters characteristic of the continental shelf edge region (Hain et al. 1985) and in other regions of steep bathymetric relief such as seamounts and canyons (Kenney and Winn 1987; Gregr and Trites 2001). On feeding grounds, sei whales associate with oceanic frontal systems (Horwood 1987) such as the cold eastern currents in the North Pacific (Perry et al. 1999a). Sei whales migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985a). During summer in the North Pacific, the sei whale can be found from the Bering Sea to the Gulf of Alaska and down to southern California, as well as in the western Pacific from Japan to Korea. Its winter distribution is concentrated at ~20°N (Rice 1998).

Sei whales are rare in the waters off California, Oregon, and Washington (Brueggeman et al. 1990; Green et al. 1992; Barlow 1994, 1997). Less than 20 confirmed sightings were reported in that region during extensive surveys during 1991–2014 (Green et al. 1992, 1993; Hill and Barlow 1992; Carretta and Forney 1993; Mangels and Gerrodette 1994; Von Saunder and Barlow 1999; Barlow 2003, 2010, 2014; Forney 2007; Carretta et al. 2019). Based on surveys conducted in 1991–2008, the estimated abundance of sei whales off the coasts of Oregon and Washington was 52 (Barlow 2010); for 2014, the abundance estimate was 468 (Barlow 2016). Two sightings of four individuals were made during the June–July 2012 L-DEO Juan de Fuca plate seismic survey off Washington/Oregon (RPS 2012b). No sei whales were sighted during the July 2012 L-DEO seismic surveys off Oregon and Washington (RPS 2012a,c).

Off the west coast of B.C., 4002 sei whales were caught from 1908–1967; the majority were taken from 1960–1967 during April–June (Gregr et al. 2000). The pattern of seasonal abundance suggested that the whales were caught as they migrated to summer feeding grounds, with the peak of the migration in July and offshore movement in summer, from ~25 km to ~100 km from shore (Gregr et al. 2000). Historical whaling data show that sei whales used to be distributed along the continental slope of B.C. and over a large area off the northwest coast of Vancouver Island (Gregr and Trites 2001).

Sei whales are now considered rare in Pacific waters of the U.S. and Canada; in B.C., there were no sightings in the late 1900s after whaling ceased (Gregr et al. 2006). A single sei whale was seen off southeastern Moresby Island in Hecate Strait coastal surveys in the summers of 2004/2005 (Williams and Thomas 2007). Ford (2014) only reported two sightings for B.C., both of those far offshore from Haida Gwaii. Possible sei whale vocalizations were detected off the west coast of Vancouver Island during spring and summer 2006 and 2007 (Ford et al. 2010b). Gregr and Trites (2001) proposed that the area off northwestern Vancouver Island and the continental slope may be critical habitat for sei whales because of favorable feeding conditions; however, no critical habitat has been designated (Parks Canada 2016). Sei whales could be encountered during the proposed survey, although this species is considered rare in these waters.

3.3.1.6 Fin Whale (*Balaenoptera physalus*)

The fin whale is widely distributed in all the World's oceans (Gambell 1985b), although it is most abundant in temperate and cold waters (Aguilar and García-Vernet 2018). Nonetheless, its overall range and distribution are not well known (Jefferson et al. 2015). A review of fin whale distribution in the North Pacific noted the lack of sightings across pelagic waters between eastern and western winter areas (Mizroch et al. 2009). Fin whales most commonly occur offshore, but can also be found in coastal areas (Jefferson et al. 2015).

Most populations migrate seasonally between temperate waters where mating and calving occur in winter, and polar waters where feeding occurs in summer (Aguilar and García-Vernet 2018). Some animals may remain at high latitudes in winter or low latitudes in summer (Edwards et al. 2015). The northern and southern fin whale populations likely do not interact owing to their alternate seasonal migration; the resulting genetic isolation has led to the recognition of two subspecies, *B. physalus quoyi* and *B. p. physalus* in the Southern and Northern hemispheres, respectively (Anguilar and García-Vernet 2018). The fin whale is known to use the shelf edge as a migration route (Evans 1987). Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily, or because the contours are areas of high biological productivity. However, fin whale movements have been reported to be complex (Jefferson et al. 2015). Stafford et al. (2009) noted that sea-surface temperature is a good predictor variable for fin whale call detections in the North Pacific.

North Pacific fin whales summer from the Chukchi Sea to California and winter from California southwards (Gambell 1985b). Information about the seasonal distribution of fin whales in the North Pacific has been obtained from the detection of fin whale calls by bottom-mounted, offshore hydrophone arrays along the U.S. Pacific coast, in the central North Pacific, and in the western Aleutian Islands (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2007, 2009). Fin whale calls are recorded in the North Pacific year-round (e.g., Moore et al. 2006; Stafford et al. 2007, 2009; Edwards et al. 2015). In the central North Pacific, the Gulf of Alaska, and Aleutian Islands, call rates peak during fall and winter (Moore et al. 1998, 2006; Watkins et al. 2000a,b; Stafford et al. 2009).

Fin whales are routinely sighted during surveys off Oregon and Washington (Barlow and Forney 2007; Barlow 2010, 2016; Adams et al. 2014; Calambokidis et al. 2015; Edwards et al. 2015; Carretta et al. 2019), including in coastal as well as offshore waters. They have also been detected acoustically in those waters during June–August (Edwards et al. 2015). Eight fin whale sightings (19 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey; sightings were made in waters 2369–3940 m deep (RPS 2012b). Fourteen fin whale sightings (28 animals) were made during the July 2012 L-DEO seismic surveys off southern Washington (RPS 2012a). No fin whales were sighted during the July 2012 L-DEO seismic survey off Oregon (RPS 2012c). Fin whales were also seen off southern Oregon during July 2012 in water >2000 m deep during surveys by Adams et al. (2014).

From 1908–1967, 7605 fin whales were caught off the west coast of B.C. by whalers; catches increased gradually from March to a peak in July, then decreased rapidly to very few in September and October (Gregr et al. 2000). Fin whales occur throughout B.C. waters near and past the continental shelf break, as well as in inshore waters (Ford 2014). Williams and Thomas (2007) estimated fin whale abundance in inland coastal B.C. waters at 496 based on surveys conducted in 2004 and 2005. Best et al. (2015) provided an estimate of 329 whales based on surveys during 2004–2008. Although fin whale records exist throughout the year, few sightings have been made from November through March (Ford 2014; Edwards et al. 2015). Fin whales were the second most common cetacean sighted during DFO surveys in 2002–2008 (Ford et al. 2010a). They appear to be more common in northern B.C., but sightings have been made along the shelf edge and in deep waters off western Vancouver Island (Ford et al. 2010a; Calambokidis et al. 2003; Ford 2014). Acoustic detections have been made throughout the year in pelagic waters west of Vancouver Island (Edwards et al. 2015). Calls were detected from February through July 2006 at Union Seamount off northwestern Vancouver Island, and from May through September at La Pérouse Bank (Ford et al. 2010b). Gregr and Trites (2001) proposed that the area off northwestern Vancouver Island and the continental slope may be critical habitat for fin whales because of favorable feeding conditions; however, no critical habitat has been designated (Parks Canada 2016). Fin whales are likely to be encountered in the proposed survey area.

3.3.1.7 Blue Whale (*Balaenoptera musculus*)

The blue whale has a cosmopolitan distribution and tends to be pelagic, only coming nearshore to feed and possibly to breed (Jefferson et al. 2015). Although it has been suggested that there are at least five subpopulations of blue whales in the North Pacific (NMFS 1998), analysis of blue whale calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones (see Stafford et al. 1999, 2001, 2007; Watkins et al. 2000a; Stafford 2003) suggests that there are two separate populations: the eastern and central (formerly western) stocks (Carretta et al. 2019). The status of these two populations could differ substantially, as little is known about the population size in the western North Pacific (Branch et al. 2016). Broad-scale acoustic monitoring indicates that blue whales occurring in the northeast Pacific during summer and fall may winter in the eastern tropical Pacific (Stafford et al. 1999, 2001).

In the North Pacific, blue whale calls are detected year-round (Stafford et al. 2001, 2009; Moore et al. 2002b, 2006; Monnahan et al. 2014). Stafford et al. (2009) reported that sea-surface temperature is a good predictor variable for blue whale call detections in the North Pacific. The distribution of the species, at least during times of the year when feeding is a major activity, occurs in areas that provide large seasonal concentrations of euphausiids (Yochem and Leatherwood 1985). The eastern North Pacific stock feeds in California waters from June–November (Calambokidis et al. 1990; Mate et al. 1999). There are nine BIAs for feeding blue whales off the coast of California (Calambokidis et al. 2015), and core areas have also been identified there (Irvine et al. 2014).

Blue whales are considered rare off Oregon, Washington, and B.C. (Buchanan et al. 2001; Gregr et al. 2006; Ford 2014), although satellite-tracked individuals have been reported off the coast (Bailey et al. 2009). Based on modeling of the dynamic topography of the region, blue whales could occur in relatively high densities off Oregon during summer and fall (Pardo et al. 2015: Hazen et al. 2017). Densities along the U.S. west coast, including Oregon, were predicted to be highest in shelf waters, with lower densities in deeper offshore areas (Becker et al. 2012; Calambokidis et al. 2015). Blue whales have been detected acoustically off Oregon (McDonald et al. 1995; Stafford et al. 1998; Von Saunder and Barlow 1999).

Whalers used to take blue whales in offshore waters of B.C.; from 1908–1967, 1398 blue whales were caught (Gregr et al. 2000). Since then, sightings have been rare (Ford 2014; DFO 2017b) and there is no abundance estimate for B.C. waters (Nichol and Ford 2012). During surveys of B.C. waters from 2002–2013, 16 sightings of blue whales were made, all of which occurred just to the south or west of Haida Gwaii during June, July, and August (Ford 2014). Seventeen blue whales have been photo identified off Haida Gwaii, B.C., and three were matched with whales occurring off California (Calambokidis et al. 2004b; Nichol and Ford 2012; Ford 2014). There have also been sightings off Vancouver Island during summer and fall (Calambokidis et al. 2004b; Ford 2014), with the most recent one reported off southwestern Haida Gwaii in July 2019 (CBC 2019). Blue whales were regularly detected on bottom-mounted hydrophones deployed off B.C. (Sears and Calambokidis 2002). Blue whale calls off Vancouver Island begin during August, increase in September and October, continue through November–February, and decline by March (Burtenshaw et al. 2004; Ford et al. 2010b; Ford 2014). They were detected on La Pérouse Bank, off southwestern Vancouver Island, during September 2007 but no calls were detected at Union Seamount, offshore from northwestern Vancouver Island (Ford et al. 2010b). Blue whales could be encountered in the proposed survey area, but are considered rare in the region.

3.3.2 Odontocetes

3.3.2.1 Sperm Whale (*Physeter macrocephalus*)

The sperm whale is widely distributed, occurring from the edge of the polar pack ice to the Equator in both hemispheres, with the sexes occupying different distributions (Whitehead 2018). In general, it is distributed over large temperate and tropical areas that have high secondary productivity and steep underwater topography, such as volcanic islands (Jaquet and Whitehead 1996). Its distribution and relative abundance can vary in response to prey availability, most notably squid (Jaquet and Gendron 2002). Females generally inhabit waters >1000 m deep at latitudes <40º where sea surface temperatures are <15ºC; adult males move to higher latitudes as they grow older and larger in size, returning to warm-water breeding grounds according to an unknown schedule (Whitehead 2018).

Sperm whales are distributed widely across the North Pacific (Rice 1989). Off California, they occur year-round (Dohl et al. 1983; Barlow 1995; Forney et al. 1995), with peak abundance from April to mid-June and from August to mid-November (Rice 1974). Off Oregon, sperm whales are seen in every season except winter (Green et al. 1992). Sperm whales were sighted during surveys off Oregon in October 2011 and off Washington in June 2011 (Adams et al. 2014). Sperm whale sightings were also made off Oregon and Washington during the 2014 Southwest Fisheries Science Center (SWFSC) vessel survey (Barlow 2016). Sperm whales were detected acoustically in waters off Oregon and Washington in August 2016 during the SWFSC Passive Acoustics Survey of Cetacean Abundance Levels (PASCAL) study using drifting acoustic recorders (Keating et al. 2018). Oleson et al. (2009) noted a significant diel pattern in the occurrence of sperm whale clicks at offshore and inshore monitoring locations off Washington, whereby clicks were more commonly heard during the day at the offshore site and at night at the inshore location, suggesting possible diel movements up and down the slope in search of prey. Sperm whale acoustic detections were also reported at an inshore site from June through January 2009, with an absence of calls during February–May (Širović et al. 2012).

From 1908–1967, 6158 sperm whales were caught off the west coast of B.C. They were taken in large numbers in April, with a peak in May. Analysis of data on catch locations, sex of the catch, and fetus lengths indicated that males and females were both 50–80 km from shore while mating in April and May, and that by July and August, adult females had moved to waters >100 km offshore to calve), and adult males had moved to within ~25 km of shore (Gregr et al. 2000). At least in the whaling era, females did not travel north of Vancouver Island whereas males were observed in deep water off Haida Gwaii (Gregr et al. 2000). After the whaling era, sperm whales have been sighted and detected acoustically in B.C. waters throughout the year, with a peak during summer (Ford 2014). Acoustic detections at La Pérouse Bank off southwestern Vancouver Island have been recorded during spring and summer (Ford et al. 2010b). Sightings west of Vancouver Island and Haida Gwaii indicate that this species still occurs in B.C. in small numbers (Ford 2014). A single sperm whale was sighted during the 2009 ETOMO survey, west of the proposed survey area (Holst 2017). Based on whaling data, Gregr and Trites (2001) proposed that the area off northwestern Vancouver Island and the continental slope may be critical habitat for male sperm whales because of favorable feeding conditions; however, no critical habitat has been designated (Parks Canada 2016). Sperm whales are likely to be encountered in the proposed survey area.

3.3.2.2 Pygmy and Dwarf Sperm Whales (*Kogia breviceps and K. sima*)

Dwarf and pygmy sperm whales are distributed throughout tropical and temperate waters of the Atlantic, Pacific and Indian oceans, but their precise distributions are unknown because much of what we know of the species comes from strandings (McAlpine 2018). They are difficult to sight at sea, because of their dive behavior and perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). The two species are often difficult to distinguish from one another when sighted (McAlpine 2018).

Both *Kogia* species are sighted primarily along the continental shelf edge and slope and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998; Jefferson et al. 2015). Stomach content analyses from stranded whales further support this distribution (McAlpine 2018). Recent data indicate that both *Kogia* species feed in the water column and on/near the seabed, likely using echolocation to search for prey (McAlpine 2018). Several studies have suggested that pygmy sperm whales live and feed mostly beyond the continental shelf edge, whereas dwarf sperm whales tend to occur closer to shore, often over the continental shelf and slope (Rice 1998; Wang et al. 2002; MacLeod et al. 2004; McAlpine 2018). It has also been suggested that the pygmy sperm whale is more temperate and the dwarf sperm whale more tropical, based at least partially on live sightings at sea from a large database from the eastern tropical Pacific (Wade and Gerrodette 1993; McAlpine 2018).

Pygmy and dwarf sperm whales are rarely sighted off Oregon and Washington, with only one sighting of an unidentified *Kogia* sp. beyond the U.S. EEZ, during the 1991–2014 NOAA vessel surveys (Carretta et al. 2019). Norman et al. (2004) reported eight confirmed stranding records of pygmy sperm whales for Oregon and Washington, five of which occurred during autumn and winter. There are several unconfirmed sighting reports of the pygmy sperm whale from the Canadian west coast (Baird et al. 1996). There is a stranding record of a pygmy sperm whale for northeastern Vancouver Island (Ford 2014), and there is a single dwarf sperm whale stranding record for southwestern Vancouver Island in September 1981 (Ford 2014). Willis and Baird (1998) state that the dwarf sperm whale is likely found in B.C. waters more frequently than recognized, but Ford (2014) suggested that the presence of *Kogia* spp. in B.C. waters is extralimital. Despite the limited number of sightings, it is possible that pygmy or dwarf sperm whales could be encountered within the proposed project area.

3.3.2.3 Cuvier's Beaked Whale (*Ziphius cavirostris*)

Cuvier's beaked whale is probably the most widespread and common of the beaked whales, although it is not found in high-latitude polar waters (Heyning 1989; Baird 2018a). It is rarely observed at sea and is known mostly from strandings; it strands more commonly than any other beaked whale (Heyning 1989). Cuvier's beaked whale is found in deep water in the open ocean and over and near the continental slope (Gannier and Epinat 2008; Baird 2018a). Its inconspicuous blows, deep-diving behavior, and tendency to avoid vessels all help to explain the infrequent sightings (Barlow and Gisiner 2006).

The population in the California Current LME seems to be declining (Moore and Barlow 2013). Nonetheless, MacLeod et al. (2006) reported numerous sightings and strandings along the Pacific coast of the U.S. Cuvier's beaked whale is the most common beaked whale off the U.S. west coast (Barlow 2010), and it is the beaked whale species that has stranded most frequently on the coasts of Oregon and Washington. From 1942–2010, there were 23 reported Cuvier's beaked whale strandings in Oregon and

Washington (Moore and Barlow 2013). Most (75%) Cuvier's beaked whale strandings reported occurred in Oregon (Norman et al. 2004).

Four beaked whale sightings were reported in water depths >2000 m off Oregon/Washington during surveys in 2008 (Barlow 2010). None were seen in 1996 or 2001 (Barlow 2003), and several were recorded from 1991–1995 (Barlow 1997). One Cuvier's beaked whale sighting during surveys in 2014 (Barlow 2016). Acoustic monitoring in Washington offshore waters detected Cuvier's beaked whale calls between January and November 2011 (Ŝirović et al. 2012b *in* USN 2015). Cuvier's beaked whales were detected acoustically in waters off Oregon and Washington in August 2016 during the SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018). Records of Cuvier's beaked whale in B.C. are scarce, although 20 strandings, one incidental catch, and five sightings have been reported, including off western Vancouver Island (Ford 2014). Most strandings have been reported in summer (Ford 2014). Cuvier's beaked whales could be encountered during the proposed survey.

3.3.2.4 Baird's Beaked Whale (*Berardius bairdii*)

Baird's beaked whale has a fairly extensive range across the North Pacific north of 30˚N, and strandings have occurred as far north as the Pribilof Islands (Rice 1986). Two forms of Baird's beaked whales have been recognized – the common slate-gray form and a smaller, rare black form (Morin et al. 2017). The gray form is seen off Japan, in the Aleutians, and on the west coast of North America, whereas the black from has been reported for northern Japan and the Aleutians (Morin et al. 2017). Recent genetic studies suggest that the black form could be a separate species (Morin et al. 2017). Baird's beaked whale is currently divided into three distinct stocks: Sea of Japan, Okhotsk Sea, and Bering Sea/eastern North Pacific (Balcomb 1989; Reyes 1991). Baird's beaked whales sometimes are seen close to shore, but their primary habitat is over or near the continental slope and oceanic seamounts in waters 1000–3000 m deep (Jefferson et al. 2015).

Along the U.S. west coast, Baird's beaked whales have been sighted primarily along the continental slope (Green et al. 1992; Becker et al. 2012; Carretta et al. 2019) from late spring to early fall (Green et al. 1992). The whales move out from those areas in winter (Reyes 1991). In the eastern North Pacific Ocean, Baird's beaked whales apparently spend the winter and spring far offshore, and in June, they move onto the continental slope, where peak numbers occur during September and October. Green et al. (1992) noted that Baird's beaked whales on the U.S. west coast were most abundant in the summer, and were not sighted in the fall or winter. MacLeod et al. (2006) reported numerous sightings and strandings of *Berardius* spp. off the U.S. west coast.

Green et al. (1992) sighted five groups during 75,050 km of aerial survey effort in 1989–1990 off Washington/Oregon spanning coastal to offshore waters: two in slope waters and three in offshore waters. Two groups were sighted during summer/fall 2008 surveys off Washington/Oregon, in waters >2000 m deep (Barlow 2010). Acoustic monitoring offshore Washington detected Baird's beaked whale pulses during January through November 2011, with peaks in February and July (Ŝirović et al. 2012b *in* USN 2015). Baird's beaked whales were detected acoustically in the waters off Oregon and Washington in August 2016 during the SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018).

There are whaler's reports of Baird's beaked whales off the west coast of Vancouver Island throughout the whaling season (May–September), especially in July and August (Reeves and Mitchell 1993). From 1908–1967, there was a recorded catch of 41 Baird's beaked whales, which were not favored because of their small size and low commercial value (Gregr et al. 2000). Twenty-four sightings have been made in B.C. since the whaling era, including off the west coast of Vancouver Island (Ford 2014).

Three strandings have also been reported, including one on northeastern Haida Gwaii and two on the west coast of Vancouver Island. Baird's beaked whales could be encountered in the proposed survey area.

3.3.2.5 Blainville's Beaked Whale (*Mesoplodon densirostris*)

Blainville's beaked whale is found in tropical and warm temperate waters of all oceans (Pitman 2018). It has the widest distribution throughout the world of all *Mesoplodon* species (Pitman 2018). Like other beaked whales, Blainville's beaked whale is generally found in waters 200–1400 m deep (Gannier 2000; Jefferson et al. 2015). Occasional occurrences in cooler, higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). MacLeod et al. (2006) reported stranding and sighting records in the eastern Pacific ranging from 37.3°N to 41.5°S. However, none of the 36 beaked whale stranding records in Oregon and Washington during 1930–2002 included Blainville's beaked whale (Norman et al. 2004). One Blainville's beaked whale was found stranded (dead) on the Washington coast in November 2016 (COASST 2016).

There was one acoustic encounter with Blainville's beaked whales recorded in Quinault Canyon off Washington in waters 1400 m deep during 2011 (Baumann-Pickering et al. 2014). Blainville's beaked whales were not detected acoustically off Washington or Oregon during the August 2016 SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018). No sightings have been made off B.C. (Ford 2014). Although Blainville's beaked whales could be encountered during the proposed survey, an encounter would be unlikely because the proposed survey area is beyond the northern limits of this tropical species' usual distribution.

3.3.2.6 Hubbs' Beaked Whale (*Mesoplodon carlhubbsi*)

Hubbs' beaked whale occurs in temperate waters of the North Pacific (Mead 1989). Its distribution appears to be correlated with the deep subarctic current (Mead et al. 1982). Numerous stranding records have been reported for the west coast of the U.S. (MacLeod et al. 2006). Most are from California, but at least seven strandings have been recorded along the B.C. coast as far north as Prince Rupert (Mead 1989; Houston 1990a; Willis and Baird 1998; Ford 2014). Two strandings are known from Washington/Oregon (Norman et al. 2004). In addition, at least two sightings off Oregon/Washington, but outside the U.S. EEZ, were reported by Carretta et al. (2019). During the 2016 SWFSC PASCAL study using drifting acoustic recorders, detections were made of beaked whale sounds presumed to be from Hubbs' beaked whales off Washington and Oregon during August (Griffiths et al. submitted manuscript cited *in* Keating et al. 2018). There have been no confirmed sightings of Hubbs' beaked whales in B.C. This species seems to be less common in the proposed survey area than some of the other beaked whales, but it could be encountered during the survey.

3.3.2.7 Stejneger's Beaked Whale (*Mesoplodon stejnegeri*)

Stejneger's beaked whale occurs in subarctic and cool temperate waters of the North Pacific (Mead 1989). Most records are from Alaskan waters, and the Aleutian Islands appear to be its center of distribution (Mead 1989; Wade et al. 2003). After Cuvier's beaked whale, Stejneger's beaked whale was the second most commonly stranded beaked whale species in Oregon and Washington (Norman et al. 2004). Stejneger's beaked whale calls were detected during acoustic monitoring offshore Washington between January and June 2011, with an absence of calls from mid-July–November 2011 (Ŝirović et al. 2012b *in* USN 2015). Analysis of these data suggest that this species could be more than twice as prevalent in this area than Baird's beaked whale (Baumann-Pickering et al. 2014). Stejneger's beaked whales were also detected acoustically in waters off Oregon and Washington in August 2016 during the SWFSC PASCAL study using drifting acoustic recorders (Keating et al. 2018).

At least five stranding records exist for B.C. (Houston 1990b; Willis and Baird 1998; Ford 2014), including two strandings on the west coast of Haida Gwaii and two strandings on the west coast of Vancouver Island (Ford 2014). A possible sighting was made on the east coast of Vancouver Island (Ford 2014). Stejneger's beaked whales could be encountered during the proposed survey.

3.3.2.8 Common Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin is distributed worldwide in coastal and shelf waters of tropical and temperate oceans (Jefferson et al. 2015). There are two distinct bottlenose dolphin types: a shallow water type, mainly found in coastal waters, and a deep-water type, mainly found in oceanic waters (Duffield et al. 1983; Hoelzel et al. 1998; Walker et al. 1999). Coastal common bottlenose dolphins exhibit a range of movement patterns including seasonal migration, year-round residency, and a combination of long-range movements and repeated local residency (Wells and Scott 2009).

Bottlenose dolphins occur frequently off the coast of California, and sightings have been made as far north as 41ºN, but few records exist for Oregon and Washington (Carretta et al. 2019). Three sightings and one stranding of bottlenose dolphins have been documented in Puget Sound since 2004 (Cascadia Research 2011 *in* USN 2015). It is possible that offshore bottlenose dolphins may range as far north as the proposed survey area during warm-water periods (Carretta et al. 2019). Adams et al. (2014) made one sighting off Washington during September 2012. There are no confirmed records of bottlenose dolphins for B.C., although an unconfirmed record exists for offshore waters (Baird et al. 1993). It is possible, although unlikely, that bottlenose dolphins could be encountered in the proposed survey area.

3.3.2.9 Striped Dolphin (*Stenella coeruleoalba*)

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters from ~50°N to 40°S (Perrin et al. 1994; Jefferson et al. 2015). It occurs primarily in pelagic waters, but has been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015). The striped dolphin is typically found in waters outside the continental shelf and is often associated with convergence zones and areas of upwelling; however, it has also been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2015).

Striped dolphins regularly occur off California (Becker et al. 2012), including as far offshore as ~300 n.mi. during the NOAA Fisheries vessel surveys (Carretta et al. 2019). However, few sightings have been made off Oregon, and no sightings have been reported for Washington (Carretta et al. 2019). However, strandings have occurred along the coasts of Oregon and Washington (Carretta et al. 2016). During surveys off the U.S. west coast in 2014, striped dolphins were seen as far north as 44ºN; based on those sightings, Barlow (2016) calculated an abundance estimate of 13,171 striped dolphins for Oregon/Washington. The abundance estimates for 2001, 2005, and 2008 were zero (Barlow 2016).

Striped dolphins are rare in the waters of B.C. and are considered extralimital there (Ford 2014). There is a total of 14 confirmed records of stranded individuals or remains for Vancouver Island (Ford 2014). A single confirmed sighting was made in September 2019 in the Strait of Juan de Fuca (Pacific Whale Watch Association 2019). One bycatch record exists in waters far offshore from Vancouver Island (Ford 2014). It is possible, although unlikely, that striped dolphins could be encountered in the proposed survey area.

3.3.2.10 Short-beaked Common Dolphin (*Delphinus delphis*)

The short-beaked common dolphin is found in tropical and warm temperate oceans around the world (Jefferson et al. 2015), ranging from ~60ºN to ~50ºS (Jefferson et al. 2015). It is the most abundant dolphin species in offshore areas of warm-temperate regions in the Atlantic and Pacific (Perrin 2018). It can be found in oceanic and coastal habitats; it is common in coastal waters 200–300 m deep and is also associated with prominent underwater topography, such as seamounts (Evans 1994). Short-beaked common dolphins have been sighted as far as 550 km from shore (Barlow et al. 1997).

The distribution of short-beaked common dolphins along the U.S. west coast is variable and likely related to oceanographic changes (Heyning and Perrin 1994; Forney and Barlow 1998). It is the most abundant cetacean off California; some sightings have been made off Oregon, in offshore waters (Carretta et al. 2019). During surveys off the west coast in 2014 and 2017, sightings were made as far north as 44°N (Barlow 2016; SIO n.d.). Based on the absolute dynamic topography of the region, short-beaked common dolphins could occur in relatively high densities off Oregon during July–December (Pardo et al. 2015). In contrast, habitat modeling predicted moderate densities of common dolphins off the Columbia River estuary during summer, with lower densities off southern Oregon (Becker et al. 2014). There are three stranding records for B.C., including one for northwestern Vancouver Island, one for the Strait of Juan de Fuca, and one for Hecate Strait (Ford 2014). Common dolphins could be encountered in the proposed survey area.

3.3.2.11 Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*)

The Pacific white-sided dolphin is found in cool temperate waters of the North Pacific from the southern Gulf of California to Alaska. Across the North Pacific, it appears to have a relatively narrow distribution between 38°N and 47°N (Brownell et al. 1999). In the eastern North Pacific Ocean, the Pacific white-sided dolphin is one of the most common cetacean species, occurring primarily in shelf and slope waters (Green et al. 1993; Barlow 2003, 2010). It is known to occur close to shore in certain regions, including (seasonally) southern California (Brownell et al. 1999).

Results of aerial and shipboard surveys strongly suggest seasonal north–south movements of the species between California and Oregon/Washington; the movements apparently are related to oceanographic influences, particularly water temperature (Green et al. 1993; Forney and Barlow 1998; Buchanan et al. 2001). During winter, this species is most abundant in California slope and offshore areas; as northern waters begin to warm in the spring, it appears to move north to slope and offshore waters off Oregon/Washington (Green et al. 1992, 1993; Forney 1994; Forney et al. 1995; Buchanan et al. 2001; Barlow 2003). The highest encounter rates off Oregon and Washington have been reported during March–May in slope and offshore waters (Green et al. 1992). Similarly, Becker et al. (2014) predicted relatively high densities off southern Oregon in shelf and slope waters.

Based on year-round aerial surveys off Oregon/Washington, the Pacific white-sided dolphin was the most abundant cetacean species, with nearly all (97%) sightings occurring in May (Green et al. 1992, 1993). Barlow (2003) also found that the Pacific white-sided dolphin was one of the most abundant marine mammal species off Oregon/Washington during 1996 and 2001 ship surveys, and it was the second most abundant species reported during 2008 surveys (Barlow 2010). Adams et al. (2014) reported numerous offshore sightings off Oregon during summer, fall, and winter surveys in 2011 and 2012. Based on surveys conducted during 2014, the abundance was estimated at 20,711 for Oregon/Washington (Barlow 2016).

Fifteen Pacific white-sided dolphin sightings (231 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey (RPS 2012b). There were fifteen Pacific white-sided dolphin sightings (462 animals) made during the July 2012 L-DEO seismic surveys off southern Washington (RPS 2012a). This species was not sighted during the July 2012 L-DEO seismic survey off Oregon (RPS 2012c). One group of 10 Pacific white-sided dolphins was sighted during the 2009 ETOMO survey west of the proposed survey area (Holst 2017).

Pacific white-sided dolphins are common throughout the waters of B.C., including Dixon Entrance, Hecate Strait, Queen Charlotte Sound, the west coast of Haida Gwaii, as well as western Vancouver Island, and the mainland coast (Ford 2014). Stacey and Baird (1991a) compiled 156 published and unpublished records to 1988 of the Pacific white-sided dolphin within the Canadian 320-km extended EEZ. These dolphins move inshore and offshore seasonally (Stacey and Baird 1991a). There were inshore records for all months except July, and offshore records from all months except December. Offshore sightings were much more common than inshore sightings, especially in June–October; the mean water depth was ~1100 m. Ford et al. (2011b) reported that most sightings occur in water depths <500 m and within 20 km from shore. Williams and Thomas (2007) estimated an abundance of 25,900 Pacific white-sided dolphins in inshore coastal B.C. waters based on surveys conducted in 2004 and 2005. Best et al. (2015) provided an estimate of 22,160 individuals based on surveys during 2004–2008. Pacific white-sided dolphins are likely to be common in the proposed survey area.

3.3.2.12 Northern Right Whale Dolphin (*Lissodelphis borealis*)

The northern right whale dolphin is found in cool temperate and sub-arctic waters of the North Pacific, from the Gulf of Alaska to near northern Baja California, ranging from 30°N to 50°N (Reeves et al. 2002). In the eastern North Pacific Ocean, the northern right whale dolphin is one of the most common marine mammal species, occurring primarily in shelf and slope waters ~100 to >2000 m deep (Green et al. 1993; Barlow 2003). The northern right whale dolphin comes closer to shore where there is deep water, such as over submarine canyons (Reeves et al. 2002).

Aerial and shipboard surveys suggest seasonal inshore-offshore and north-south movements in the eastern North Pacific Ocean between California and Oregon/Washington; the movements are believed to be related to oceanographic influences, particularly water temperature and presumably prey distribution and availability (Green et al. 1993; Forney and Barlow 1998; Buchanan et al. 2001). Green et al. (1992, 1993) found that northern right whale dolphins were most abundant off Oregon/Washington during fall, less abundant during spring and summer, and absent during winter, when this species presumably moves south to warmer California waters (Green et al. 1992, 1993; Forney 1994; Forney et al. 1995; Buchanan et al. 2001; Barlow 2003).

Becker et al. (2014) predicted relatively high densities off southern Oregon, and moderate densities off northern Oregon and Washington. Based on year-round aerial surveys off Oregon/Washington, the northern right whale dolphin was the third most abundant cetacean species, concentrated in slope waters but also occurring in water out to ~550 km offshore (Green et al. 1992, 1993). Barlow (2003, 2010) also found that the northern right whale dolphin was one of the most abundant marine mammal species off Oregon/Washington during 1996, 2001, 2005, and 2008 ship surveys. Offshore sightings were made in the waters of Oregon during summer, fall, and winter surveys in 2011 and 2012 (Adams et al. 2014).

There are 47 records for B.C., mostly in deep water off the west coast of Vancouver Island; however, sightings have also been made in deep water off Haida Gwaii (Ford 2014). Most sightings have occurred in water depths >900 m (Baird and Stacey 1991a). One group of six northern right whale dolphins was seen west of Vancouver Island in water deeper than 2500 m during a survey from Oregon to Alaska (Hauser and Holst 2009). Northern right whale dolphins are likely to be encountered in the proposed survey area.

3.3.2.13 Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is distributed worldwide in mid-temperate and tropical oceans (Kruse et al. 1999). although it shows a preference for mid-temperate waters of the shelf and slope between 30° and 45° (Jefferson et al. 2014). Although it occurs from coastal to deep water (~200–1000 m depth), it shows a strong preference for mid-temperate waters of upper continental slopes and steep shelf-edge areas (Hartman 2018).

Off the U.S. west coast, Risso's dolphin is believed to make seasonal north-south movements related to water temperature, spending colder winter months off California and moving north to waters off Oregon/Washington during the spring and summer as northern waters begin to warm (Green et al. 1992, 1993; Buchanan et al. 2001; Barlow 2003; Becker 2007). The distribution and abundance of Risso's dolphins are highly variable from California to Washington, presumably in response to changing oceanographic conditions on both annual and seasonal time scales (Forney and Barlow 1998; Buchanan et al. 2001). The highest densities were predicted along the coasts of Washington, Oregon, and central and southern California (Becker et al. 2012). Off Oregon and Washington, Risso's dolphins are most abundant over continental slope and shelf waters during spring and summer, less so during fall, and rare during winter (Green et al. 1992, 1993). Green et al. (1992, 1993) reported most Risso's dolphin groups off Oregon between ~45 and 47ºN. Several sightings were made off southern Oregon during surveys in 1991–2014 (Carretta et al. 2019). Sightings during ship surveys in summer/fall 2008 were mostly between ~30 and 38ºN; none were reported in Oregon/Washington (Barlow 2010). Based on 2014 survey data, the abundance for Oregon/Washington was estimated at 430 (Barlow 2016).

Risso's dolphin was once considered rare in B.C., but there have been numerous sightings since the 1970s (Ford 2014). In B.C., most sightings have been made in Gwaii Haanas National Park Reserve, Haida Gwaii, but there have also been sightings in Dixon Entrance, off the west coast of Haida Gwaii, Queen Charlotte Sound, as well as to the west of Vancouver Island (Ford 2014). Strandings have mainly been reported for the Strait of Georgia (Ford 2014). Risso's dolphins could be encountered in the proposed survey area.

3.3.2.14 False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found worldwide in tropical and temperate waters, generally between 50ºN and 50ºS (Odell and McClune 1999). It is widely distributed, but not abundant anywhere (Carwardine 1995). The false killer whale generally inhabits deep, offshore waters, but sometimes is found over the continental shelf and occasionally moves into very shallow (Jefferson et al. 2015; Baird 2018b). It is gregarious and forms strong social bonds, as is evident from its propensity to strand en masse (Baird 2018b). In the eastern North Pacific, it has been reported only rarely north of Baja California (Leatherwood et al. 1982, 1987; Mangels and Gerrodette 1994); however, the waters off the U.S. west coast all the way north to Alaska are considered part of its secondary range (Jefferson et al. 2015).

Its occurrence in Washington/Oregon is associated with warm-water incursions (Buchanan et al. 2001). However, no sightings of false killer whales were made along the U.S. west coast during surveys conducted from 1986–2001 (Ferguson and Barlow 2001, 2003; Barlow 2003) or in 2005 and 2008 (Forney 2007; Barlow 2010). One pod of false killer whales occurred in Puget Sound for several months during the 1990s (USN 2015). Two false killer whales were reported stranded along the Washington coast during 1930–2002, both in El Niño years (Norman et al. 2004).

Stacey and Baird (1991b) suggested that false killer whales are at the limit of their distribution in Canada and have always been rare. Sightings have been made along the northern and central mainland B.C. coast, as well as in Queen Charlotte Strait, Strait of Georgia, and along the west coast of Vancouver Island; there are no records for deeper water in the proposed survey area (Ford 2014). This species is unlikely to be encountered during the proposed survey.

3.3.2.15 Killer Whale (*Orcinus orca*)

The killer whale is cosmopolitan and globally fairly abundant; it has been observed in all oceans of the world (Ford 2018). It is very common in temperate waters and also frequents tropical waters, at least seasonally (Heyning and Dahlheim 1988). Killer whales are segregated socially, genetically, and ecologically into three distinct ecotypes: residents, transients, and offshore animals. Killer whales occur in inshore inlets, along the coast, over the continental shelf, and in offshore waters (Ford 2014).

There are eight killer whale stocks recognized in the Pacific U.S.: (1) Alaska Residents, occurring from Southeast Alaska to the Aleutians and Bering Sea; (2) Northern Residents, from B.C. through parts of Southeast Alaska; (3) Southern Residents, mainly in inland waters of Washington State and southern B.C.; (4) Gulf of Alaska, Aleutians, and Bering Sea Transients, from Prince William Sound through to the Aleutians and Bering Sea; (5) AT1 Transients, from Prince William Sound through the Kenai Fjords; (6) West Coast Transients, from California through Southeast Alaska; (7) Offshore, from California through Alaska; and (8) Hawaiian (Muto et al. 2019; Carretta et al. 2019). Individuals from the ***endangered*** Southern Resident stock, as well as the Northern Resident, West Coast Transient, and Offshore stocks could be encountered in the proposed project area.

Resident killer whales mainly feed on salmon, in particular Chinook, and their movements coincide with those of their prey (Ford 2014). During the spring, summer, and fall, southern resident killer whales primarily occur in the southern Strait of Georgia, Strait of Juan de Fuca, Puget Sound, and the southern half of the west coast of Vancouver Island (Ford et al. 1994; Baird 2001; Olson et al. 2018; Carretta et al. 2019). These areas have been designated as critical habitat either by the U.S. or Canada. High-use areas along the coast of Washington have also been reported (Hanson et al. 2017, 2018) and are soon to be designated as critical habitat (NMFS 2019a).

Southern resident killer whales occur along the outer coasts of B.C. and Washington throughout the year, but individuals have been reported as far south as California and as far north as Alaska (Hanson et al. 2017, 2018; Carretta et al. 2019). There appears to be a recent occupancy shift from the Salish Sea in spring/summer to other waters, possibly offshore (Shields et al. 2018a; Maples 2019). Southern resident killer whales have been detected acoustically at Swiftsure Bank off southwestern Vancouver Island throughout the year, with peak activity during the summer (Riera et al. 2019). Southern resident whales appear to spend the majority of their time on the continental shelf, within 34 km from the coast, in water <100 m deep (Hanson et al. 2017). K/L pods primarily occur on the Washington coast, from Grays Harbor to the Columbia River; high use areas for J pod primarily occur at the western entrance of the Strait of Juan de Fuca and northern Strait of Georgia (Hanson et al. 2017). This population has decreased from a census count of 99 animals in 1995 (Carretta et al. 2019) to a current size of 75 individuals (OrcaNetwork 2021); this small population is threatened by reduced prey availability, contaminants, and vessel disturbance including noise (Williams et al. 2016; Lacy et al. 2017; DFO 2018c; Murray et al. 2019; NMFS 2021b).

In B.C., the northern residents inhabit the central and northern Strait of Georgia, Johnstone Strait, Queen Charlotte Strait, the west coast of Vancouver Island, and the entire central and north coast of mainland B.C. (Muto et al. 2019). Many sightings have been made in Dixon Entrance (which is designated as critical habitat) and eastern Hecate Strait, which is also considered important habitat (Ford 2014). Critical habitat for this population in B.C. also includes the waters off southwestern Vancouver Island, where both northern and southern resident killer whales often forage in the summer (Ford 2014). Northern resident killer whales have been detected acoustically at Swiftsure Bank off southwestern Vancouver Island throughout the year, with peak activity during summer (Riera et al. 2019).

The main diet of transient killer whales consists of marine mammals, in particular porpoises and seals. West coast transient whales (also known as Bigg's killer whales) range from Southeast Alaska to California (Muto et al. 2019). The seasonal movements of transients are largely unpredictable, although there is a tendency to investigate harbor seal haulouts off Vancouver Island more frequently during the pupping season in August and September (Baird 1994; Ford 2014). Transients have been sighted throughout B.C. waters, including the waters around Vancouver Island (Ford 2014) as well as the Salish Sea (Shields et al. 2018b). Green et al. (1992) noted that most groups seen during their surveys off Oregon and Washington were likely transients; during those surveys, killer whales were sighted only in shelf waters. Two of 17 killer whales that stranded in Oregon were confirmed as transient (Stevens et al. 1989 *in* Norman et al. 2004).

Little is known about offshore killer whales, but they occur primarily over shelf waters and feed on fish, especially sharks (Ford 2014). Dahlheim et al. (2008) reported sightings off Washington and Oregon in the summer, and sightings in the Strait of Juan de Fuca during spring. Relatively few sightings have been reported in the waters of B.C.; there have been 103 records since 1988 (Ford 2014). The number of sightings is likely influenced by the fact that these whales prefer deeper waters near the slope, where little sighting effort has taken place (Ford 2014). Most sightings are from Haida Gwaii and 15 km or more off the west coast of Vancouver Island near the continental slope (Ford et al. 1994). Offshore killer whales are mainly seen off B.C. during summer and off California during winter, but they can occur in B.C. waters year-round (Ford 2014). Based on surveys conducted during 2004–2008, Best et al. (2015) estimated that 371 killer whales (all ecotypes) occur in coastal waters of B.C.

Eleven sightings of ~536 individuals were reported off Oregon/Washington during the 2008 SWFSC vessel survey (Barlow 2010). Killer whales were sighted offshore Washington during surveys from August 2004 to September 2008 (Oleson et al. 2009). Keating et al. (2015) analyzed cetacean whistles from recordings made during 2000–2012; several killer whale acoustic detections were made offshore Washington. Killer whales were sighted off Washington in July and September 2012 (Adams et al. 2014).

Killer whales could be encountered during the proposed surveys, including northern and southern resident killer whales in their critical habitat in Canada. However, most sightings within the critical habitat off southwestern Vancouver Island have occurred closer to shore than the proposed seismic transects.

3.3.2.16 Short-finned Pilot Whale (*Globicephala macrorhynchus*)

The short-finned pilot whale is found in tropical and warm temperate waters (Olson 2018); it is seen as far south as ~40ºS and as far north as ~50ºN (Jefferson et al. 2015). Pilot whales are generally nomadic, but may be resident in certain locations, including California and Hawaii (Olson 2018). Short-finned pilot whales were common off southern California (Dohl et al. 1980) until an El Niño event occurred in 1982–1983 (Carretta et al. 2019). Few sightings were made off California/Oregon/ Washington in 1984–1992 (Green et al. 1992; Carretta and Forney 1993; Barlow 1997), but sightings remain rare (Barlow 1997; Buchanan et al. 2001; Barlow 2010). No short-finned pilot whales were seen during surveys off Oregon and Washington in 1989–1990, 1992, 1996, and 2001 (Barlow 2003). Carretta et al. (2019) reported one sighting off Oregon during 1991–2014. Several stranding events in Oregon/southern Washington have been recorded over the past few decades, including in March 1996, June 1998, and August 2002 (Norman et al. 2004).

Short-finned pilot whales are considered rare in B.C. waters (Baird and Stacey 1993; Ford 2014). There are 10 confirmed records, including three bycatch records in offshore waters, six sightings in offshore waters, and one stranding; the stranding occurred in the Strait of Juan de Fuca (Ford 2014). There are also unconfirmed records for nearshore waters of western Vancouver Island (Baird and Stacey 1993; Ford 2014). Pilot whales are expected to be rare in the proposed survey area.

3.3.2.17 Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise inhabits temperate, subarctic, and arctic waters. It is typically found in shallow water (<100 m) nearshore but is occasionally sighted in deeper offshore water (Jefferson et al. 2015); abundance declines linearly as depth increases (Barlow 1988). In the eastern North Pacific, its range extends from Point Barrow, Alaska, to Point Conception, California. Their seasonal movements appear to be inshore-offshore, rather than north-south, as a response to the abundance and distribution of food resources (Dohl et al. 1983; Barlow 1988). Genetic testing has also shown that harbor porpoises along the west coast of North America are not migratory and occupy restricted home ranges (Rosel et al. 1995).

Based on genetic data and density discontinuities, six stocks have been identified in California/Oregon/Washington: (1) Washington Inland Waters, (2) Northern Oregon/Washington Coast, (3) Northern California/Southern Oregon, (4) San Francisco-Russian River, (5) Monterey Bay, and (6) Morro Bay (Carretta et al. 2019). Harbor porpoises from the Northern Oregon/Washington and the Northern California/Southern Oregon stocks could occur in the proposed project area (Carretta et al. 2019).

Harbor porpoises inhabit coastal Oregon and Washington waters year-round, although there appear to be distinct seasonal changes in abundance there (Barlow 1988; Green et al. 1992). Green et al. (1992) reported that encounter rates were similarly high during fall and winter, intermediate during spring, and low during summer. Encounter rates were highest along the Oregon/Washington coast in the area from Cape Blanco (~43°N) to California, from fall through spring. During summer, the reported encounter rates decreased notably from inner shelf to offshore waters. Green et al. (1992) reported that 96% of harbor porpoise sightings off Oregon/Washington occurred in coastal waters <100 m deep, with a few sightings on the slope near the 200-m isobath. Similarly, predictive density distribution maps show the highest in nearshore waters along the coasts of Oregon/Washington, with very low densities beyond the 500-m isobath (Menza et al. 2016).

Based on surveys conducted during 2004 and 2005, Williams and Thomas (2007) estimated that 9120 harbor porpoises are present in inshore coastal waters of B.C. Best et al. (2015) provided an estimate of 8091 based on surveys during 2004–2008. Harbor porpoises are found along the coast year-round, primarily in coastal shallow waters, harbors, bays, and river mouths of B.C. (Osborne et al. 1988), but can also be found in deep water over the continental shelf and over offshore banks that are no deeper than 150 m (Ford 2014; COSEWIC 2016a). Many sightings exist for nearshore waters of Vancouver Island (Ford 2014), including within the proposed survey area. Occasional sightings have also been made in shallow water of Swiftsure and La Pérouse banks off southwestern Vancouver Island (Ford 2014). Harbor porpoises could be encountered in shallower water in the eastern portions of the proposed project area.

3.3.2.18 Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoise is found in temperate to subarctic waters of the North Pacific and adjacent seas (Jefferson et al. 2015). It is widely distributed across the North Pacific over the continental shelf and slope waters, and over deep (>2500 m) oceanic waters (Hall 1979). It is probably the most abundant small cetacean in the North Pacific Ocean, and its abundance changes seasonally, likely in relation to water temperature (Becker 2007).

Off Oregon and Washington, Dall's porpoise is widely distributed over shelf and slope waters, with concentrations near shelf edges, but is also commonly sighted in pelagic offshore waters (Morejohn 1979; Green et al. 1992; Becker et al. 2014; Fleming et al. 2018; Carretta et al. 2019). Combined results of various surveys out to ~550 km offshore indicate that the distribution and abundance of Dall's porpoise varies between seasons and years. North-south movements are believed to occur between Oregon/Washington and California in response to changing oceanographic conditions, particularly temperature and distribution and abundance of prey (Green et al. 1992, 1993; Mangels and Gerrodette 1994; Barlow 1995; Forney and Barlow 1998; Buchanan et al. 2001). Becker et al. (2014) predicted high densities off southern Oregon throughout the year, with moderate densities to the north. According to predictive density distribution maps, the highest densities off southern Washington and Oregon occur along the 500-m isobath (Menza et al. 2016).

Encounter rates reported by Green et al. (1992) during aerial surveys off Oregon/Washington were highest in fall, lowest during winter, and intermediate during spring and summer. Encounter rates during the summer were similarly high in slope and shelf waters, and somewhat lower in offshore waters (Green et al. 1992). Dall's porpoise was the most abundant species sighted off Oregon/Washington during 1996, 2001, 2005, and 2008 ship surveys up to ~550 km from shore (Barlow 2003, 2010). Oleson et al. (2009) reported 44 sightings of 206 individuals off Washington during surveys form August 2004 to September 2008. Dall's porpoise were seen in the waters off Oregon during summer, fall, and winter surveys in 2011 and 2012 (Adams et al. 2014).

Nineteen Dall's porpoise sightings (144 animals) were made off Washington/Oregon during the June–July 2012 L-DEO Juan de Fuca plate seismic survey (RPS 2012b). There were 16 Dall's porpoise sightings (54 animals) made during the July 2012 L-DEO seismic surveys off southern Washington (RPS 2012a). This species was not sighted during the July 2012 L-DEO seismic survey off Oregon (RPS 2012c).

Dall's porpoise is found all along the B.C. coast and is common inshore and offshore throughout the year (Jefferson 1990; Ford 2014). It is most common over the continental shelf and slope, but also occurs >2400 km from the coast (Pike and MacAskie 1969 *in* Jefferson 1990), and sightings have been made throughout the proposed survey area (Ford 2014). There appears to be a distributional shift inshore during the summer and offshore in winter (Ford 2014). Based on surveys conducted in 2004 and 2005, Williams and Thomas (2007) estimated that there are 4910 Dall's porpoises in inshore coastal waters of B.C. Best et al. (2015) provided an estimate of 5303 individuals based on surveys during 2004–2008. During a survey from Oregon to Alaska, Dall's porpoises were sighted west of Vancouver Island and Haida Gwaii in early October during the southbound transit, but none were sighted in mid-September during the northward transit; all sightings were made in water deeper than 2000 m (Hauser and Holst 2009). Dall's porpoise was the most frequently sighted marine mammal species (5 sightings or 28 animals) during the 2009 ETOMO survey west of the proposed survey area (Holst 2017). Dall's porpoise is likely to be encountered during the proposed seismic survey.

3.3.3 Pinnipeds

3.3.3.1 Guadalupe Fur Seal (*Arctocephalus townsendi*)

Most breeding and births occur at Isla Guadalupe, Mexico; a secondary rookery exists at Isla Benito del Este (Maravilla-Chavez and Lowry 1999; Aurioles-Gamboa et al. 2010). A few Guadalupe fur seals are known to occur at California sea lion rookeries in the Channel Islands, primarily San Nicolas and San Miguel islands, and sightings have also been made at Santa Barbara and San Clemente islands (Stewart et al. 1987; Carretta et al. 2019). Guadalupe fur seals prefer rocky habitat for breeding and hauling out. They generally haul out at the base of towering cliffs on shores characterized by solid rock and large lava blocks (Peterson et al. 1968), although they can also inhabit caves and recesses (Belcher and Lee 2002).

While at sea, this species usually is solitary but typically gathers in the hundreds to thousands at breeding sites.

During the summer breeding season, most adults occur at rookeries in Mexico (Carretta et al. 2019; Norris 2017 *in* USN 2019a,b). Following the breeding season, adult males tend to move northward to forage. Females have been observed feeding south of Guadalupe Island, making an average round trip of 2375 km (Ronald and Gots 2003). Several rehabilitated Guadalupe fur seals that were satellite tagged and released in central California traveled as far north as B.C. (Norris et al. 2015; Norris 2017 *in* USN 2019a,b). Fur seals younger than two years old are more likely to travel to more northerly, offshore areas than older fur seals (Norris 2017 *in* USN 2019a,b). Stranding data also indicates that fur seals younger than 2 years are more likely to occur in the proposed survey area, as this age class was most frequently reported (Lambourn et al. 2012 *in* USN 2019a,b). In 2015–2016, 175 Guadalupe fur seals stranded on the coast of California; NMFS declared this an unusual mortality event (Carretta et al. 2019). Guadalupe fur seals could be encountered during the proposed seismic surveys off the coasts of Washington and Oregon, but most animals are likely to occur at their breeding sites further south at the time of the survey.

3.3.3.2 Northern Fur Seal (*Callorhinus ursinus*)

The northern fur seal is endemic to the North Pacific Ocean and occurs from southern California to the Bering Sea, Okhotsk Sea, and Honshu Island, Japan (Muto et al. 2019). During the breeding season, most of the worldwide population of northern fur seals inhabits the Pribilof Islands in the southern Bering Sea (NMFS 2007; Lee et al. 2014; Muto et al. 2019). The rest of the population occurs at rookeries on Bogoslof Island in the Bering Sea, in Russia (Commander Islands, Robben Island, Kuril Islands), on San Miguel Island in southern California (NMFS 1993; Lee et al. 2014), and on the Farallon Islands off central California (Muto et al. 2019). In the U.S., two stocks are recognized—the Eastern Pacific and the California stocks (Muto et al. 2019). The Eastern Pacific stock ranges from the Pribilof Islands and Bogoslof Island in the Bering Sea during summer to California during winter (Muto et al. 2019).

When not on rookery islands, northern fur seals are primarily pelagic but occasionally haul out on rocky shorelines (Muto et al. 2019). During the breeding season, adult males usually come ashore in May–August and may sometimes be present until November; adult females are found ashore from June–November (Carretta et al. 2019; Muto et al. 2019). After reproduction, northern fur seals spend the next 7–8 months feeding at sea (Roppel 1984). Immature seals can remain in southern foraging areas year-round until they are old enough to mate (NMFS 2007). In November, females and pups leave the Pribilof Islands and migrate through the Gulf of Alaska to feeding areas primarily off the coasts of B.C., Washington, Oregon, and California before migrating north again to the rookeries in spring (Ream et al. 2005; Pelland et al. 2014). Males usually migrate only as far south as the Gulf of Alaska (Kajimura 1984). Ream et al. (2005) showed that migrating females moved over the continental shelf as they migrated southeasterly. Instead of following depth contours, their travel corresponded with movements of the Alaska Gyre and the North Pacific Current (Ream et al. 2005). Their foraging areas were associated with eddies, the subarctic-subtropical transition region, and coastal mixing (Ream et al. 2005; Alford et al. 2005). Some juveniles and non-pregnant females may remain in the Gulf of Alaska throughout the summer (Calkins 1986). The northern fur seals spends ~90% of its time at sea, typically in areas of upwelling along the continental slopes and over seamounts (Gentry 1981). The remainder of its life is spent on or near rookery islands or haulouts. Pups from the California stock also migrate to Washington, Oregon, and northern California after weaning (Lea et al. 2009).

Northern fur seals were seen throughout the North Pacific during surveys conducted during 1987–1990, including off Vancouver Island and in the western Gulf of Alaska (Buckland et al. 1993).

Tagged adult fur seals were tracked from the Pribilof Islands to the waters off Washington/Oregon/ California, with recorded movement throughout the proposed project area (Pelland et al. 2014). Tracked adult male fur seals that were tagged on St. Paul Island in the Bering Sea in October 2009, wintered in the Bering Sea or northern North Pacific Ocean; females migrated to the Gulf of Alaska and the California Current, including off the west coasts of Haida Gwaii and Vancouver Island (Sterling et al. 2014). Some individuals reach California by December, after which time numbers increase off the west coast of North America (Ford 2014). The peak density shift over the course of the winter and spring, with peak densities occurring in California in February, April off Oregon and Washington, and May off B.C. and Southeast Alaska (Ford 2014). The use of continental shelf and slope waters of B.C. and the northwestern U.S. by adult females during winter is well documented from pelagic sealing data (Bigg 1990).

Bonnell et al. (1992) noted the presence of northern fur seals year-round off Oregon/Washington, with the greatest numbers (87%) occurring in January–May. Northern fur seals were seen as far out from the coast as 185 km, and numbers increased with distance from land; they were 5–6 times more abundant in offshore waters than over the shelf or slope (Bonnell et al. 1992). The highest densities were seen in the Columbia River plume (~46°N) and in deep offshore waters (>2000 m) off central and southern Oregon (Bonnell et al. 1992). The waters off Washington are a known foraging area for adult females, and concentrations of fur seals were also reported to occur near Cape Blanco, Oregon, at ~42.8°N (Pelland et al. 2014).

Off B.C., females and subadult males are typically found during the winter off the continental shelf (Bigg 1990). They start arriving from Alaska during December and most will leave the B.C. waters by July (Ford 2014). Tagged adult female fur seals were shown to concentrate their habitat utilization within 200 km of the shelf break along the west coast of North America; several traveled through the proposed survey area off western Vancouver Island (Pelland et al. 2014). Ford (2014) also reported the occurrence of northern fur seals throughout B.C. waters, including Dixon Entrance, Hecate Strait, Queen Charlotte Sound, and off the west coasts of Haida Gwaii and Vancouver Island, with concentrations over the shelf and slope, especially on La Pérouse Bank, southwestern Vancouver Island. A few animals are seen in inshore waters in B.C., and individuals occasionally come ashore, usually at sea lion haulouts (e.g., Race Rocks, off southern Vancouver Island) during winter and spring (Baird and Hanson 1997). Approximately 125,000 fur seals occur in B.C. over the winter and spring (Ford 2014). Although fur seals sometimes haul out in B.C., there are no breeding rookeries.

Northern fur seals could be observed in the proposed survey area, in particular females and juveniles. However, adult males are generally ashore during the reproductive season from May–August, and adult females are generally ashore from June through November.

3.3.3.3 Northern Elephant Seal (*Mirounga angustirostris*)

The northern elephant seal breeds in California and Baja California, primarily on offshore islands, from Cedros off the west coast of Baja California, north to the Farallons in Central California (Stewart et al. 1994). Adult elephant seals engage in two long northward migrations per year, one following the breeding season, and another following the annual molt (Stewart and DeLong 1995). Between the two foraging periods, they return to land to molt, with females returning earlier than males (March–April vs. July–August). After the molt, adults then return to their northern feeding areas until the next winter breeding season. Breeding occurs from December–March (Stewart and Huber 1993). Females arrive in late December or January and give birth within ~1 week of their arrival. Juvenile elephant seals typically leave the rookeries in April or May and head north, traveling an average of 900–1000 km. Hindell (2009) noted that traveling likely takes place at depths >200 m. Most elephant seals return to their natal rookeries when they start breeding (Huber et al. 1991).

When not at their breeding rookeries, adults feed at sea far from the rookeries. Adult females and juveniles forage in the California current off California to B.C. (Le Boeuf et al. 1986, 1993, 2000). Bonnell et al. (1992) reported that northern elephant seals were distributed equally in shelf, slope, and offshore waters during surveys conducted off Oregon and Washington, as far as 150 km from shore, in waters >2000 m deep. Telemetry data indicate that they range much farther offshore than that (Stewart and DeLong 1995). Males may feed as far north as the eastern Aleutian Islands and the Gulf of Alaska, whereas females feed south of 45ºN (Le Boeuf et al. 1993; Stewart and Huber 1993). Adult male elephant seals migrate north via the California current to the Gulf of Alaska during foraging trips, and could potentially be passing through the area off Washington in May and August (migrating to and from molting periods) and November and February (migrating to and from breeding periods), but likely their presence there is transient and short-lived. Most elephant seal sightings at sea off Washington were made during June, July, and September; off Oregon, sightings were recorded from November through May (Bonnell et al. 1992). Northern elephant seal pups have been sighted at haulouts in the inland waters of Washington State (Jeffries et al. 2000), and at least three were reported to have been born there (Hayward 2003). Pupping has also been observed at Shell Island (~43.3°N) off southern Oregon, suggesting a range expansion (Bonnell et al. 1992; Hodder et al. 1998).

Race Rocks Ecological Reserve, located off southern Vancouver Island, is one of the few spots in B.C. where elephant seals regularly haul out. Based on their size and general appearance, most animals using Race Rocks are adult females or subadults, although a few adult males also haul out there. Use of Race Rocks by northern elephant seals has increased substantially in recent years, most likely as a result of the species' dramatic recovery from near extinction in the early 20th century and its tendency to be highly migratory. A peak number (22) of adults and subadults were observed in spring 2003 (Demarchi and Bentley 2004); pups have also been born there primarily during December and January (Ford 2014). Haul outs can also be found on the western and northeastern coasts of Haida Gwaii, and along the coasts of Vancouver Island (Ford 2014). Juveniles are sometimes seen molting on beaches along the coast of B.C. from December–May, but sometimes also in summer and autumn (Ford 2014). One northern elephant seal was sighted during the 2009 ETOMO survey west of the proposed survey area (Holst 2017). This species could be encountered during the proposed seismic survey.

3.3.3.4 Harbor Seal (*Phoca vitulina richardsi*)

Two subspecies of harbor seal occur in the Pacific: *P.v. stejnegeri* in the northwest Pacific Ocean and *P.v. richardsi* in the eastern Pacific Ocean. *P.v. richardsi* occurs in nearshore, coastal, and estuarine areas ranging from Baja California, Mexico, north to the Pribilof Islands in Alaska (Carretta et al. 2019). Five stocks of harbor seals are recognized along the U.S. west coast: (1) Southern Puget Sound, (2) Washington Northern Inland Waters Stock, (3) Hood Canal, (4) Oregon/Washington Coast, and (5) California (Carretta et al. 2019). The Oregon/Washington stock occurs in the proposed survey area.

Harbor seals inhabit estuarine and coastal waters, hauling out on rocks, reefs, beaches, and glacial ice flows. They are generally non-migratory, but move locally with the tides, weather, season, food availability, and reproduction (Scheffer and Slipp 1944; Fisher 1952; Bigg 1969, 1981). Female harbor seals give birth to a single pup while hauled out on shore or on glacial ice flows; pups are born from May to mid-July. When molting, which occurs primarily in late August, seals spend the majority of the time hauled out on shore, glacial ice, or other substrates. Juvenile harbor seals can travel significant distances

(525 km) to forage or disperse (Lowry et al. 2001). The smaller home range used by adults is suggestive of a strong site fidelity (Pitcher and Calkins 1979; Pitcher and McAllister 1981; Lowry et al. 2001).

Harbor seals haul out on rocks, reefs, and beaches along the U.S. west coast (Carretta et al. 2019). Jeffries et al. (2000) documented several harbor seal rookeries and haulouts along the Washington coastline; it is the only pinniped species that breeds in Washington. Pupping in Oregon and Washington occurs from April–July (Brown 1988). Bonnell et al. (1992) noted that most harbor seals sighted off Oregon and Washington were ≤20 km from shore, with the farthest sighting 92 km from the coast. Menza et al. (2016) also showed the highest predicted densities nearshore. During surveys off the Oregon and Washington coasts, 88% of at-sea harbor seals occurred over shelf waters <200 m deep, with a few sightings near the 2000-m contour, and only one sighting over deeper water (Bonnell et al. 1992). Most (68%) at-sea sightings were recorded in September and November (Bonnell et al. 1992). Harbor seals were only seen in nearshore areas during surveys on the shelf and slope in 2011 and 2012 (Adams et al. 2014). Twelve sightings occurred in nearshore waters from R/V *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a). Harbor seals were also taken as bycatch east of southern Oregon in the west coast groundfish fishery during 2002–2009 (Jannot et al. 2011).

Williams and Thomas (2007) noted an abundance estimate of 19,400 harbor seals for the inshore coastal waters of B.C. based on surveys in 2004 and 2005. Best et al. (2015) provided an abundance estimate of 24,916 seals based on coastal surveys during 2004–2008. The total population in B.C. was estimated at ~105,000 in 2008 (Ford 2014). Harbor seals occur along all coastal areas of B.C., including the western coast of Vancouver Island, with the highest concentration in the Strait of Georgia (13.1 seals per kilometre of coast); average densities elsewhere are 2.6 seals per kilometre (Ford 2014). Almost 1400 haul outs have been reported for B.C., many of them in the Strait of Georgia (Ford 2014). Given their preference for coastal waters, harbor seals could be encountered in the easternmost parts of the proposed project area.

3.3.3.5 Steller Sea Lion (*Eumetopias jubatus*)

The Steller sea lion occurs along the North Pacific Rim from northern Japan to California (Loughlin et al. 1984). It is distributed around the coasts to the outer shelf from northern Japan through the Kuril Islands and Okhotsk Sea, through the Aleutian Islands, central Bering Sea, southern Alaska, and south to California (NOAA 2019f). There are two stocks, or DPSs, of Steller sea lions – the Western and Eastern DPSs, which are divided at 144°W longitude (Muto et al. 2019). The Western DPS is listed as *endangered* and includes animals that occur in Japan and Russia (Muto et al. 2019); the Eastern DPS was delisted from *threatened* in 2013 (NMFS 2013a). Only individuals from the Eastern DPS could occur in the proposed survey area.

Steller sea lions typically inhabit waters from the coast to the outer continental shelf and slope throughout their range; they are not considered migratory, although foraging animals can travel long distances (Loughlin et al. 2003; Raum-Suryan et al. 2002). Rookeries of Steller sea lions from the Eastern DPS are located in southeast Alaska, B.C., Oregon, and California; there are no rookeries in Washington (NMFS 2013a; Muto et al. 2019). Breeding adults occupy rookeries from late-May to early-July (NMFS 2008a).

Non-breeding adults use haulouts or occupy sites at the periphery of rookeries during the breeding season (NMFS 2008a). Pupping occurs from mid-May to mid-July (Pitcher and Calkins 1981) and peaks in June (Pitcher et al. 2002). Territorial males fast and remain on land during the breeding season (NMFS 2008a). Females with pups generally stay within 30 km of the rookeries in shallow (30–120 m) water when feeding (NMFS 2008a). Tagged juvenile sea lions showed localized movements near shore (Briggs et al. 2005). Loughlin et al. (2003) reported that most (88%) at-sea movements of juvenile Steller sea lions in the Aleutian Islands were short (<15 km) foraging trips. The mean distance of juvenile sea lion trips at sea was 16.6 km, and the maximum trip distance recorded was 447 km. Long-range trips represented 6% of all trips at sea, and trip distance and duration increase with age (Loughlin et al. 2003; Call et al. 2007). Although Steller sea lions are not considered migratory, foraging animals can travel long distances outside of the breeding season (Loughlin et al. 2003; Raum-Suryan et al. 2002). During the summer, they mostly forage within 60 km from the coast; during winter, they can range up to 200 km from shore (Ford 2014).

During surveys off the coasts of Oregon and Washington, Bonnell et al. (1992) noted that 89% of sea lions occurred over the shelf at a mean distance of 21 km from the coast and near or in waters <200 m deep; the farthest sighting occurred ~40 km from shore, and the deepest sighting location was 1611 m deep. Sightings were made along the 200-m depth contour throughout the year (Bonnell et al. 1992). During aerial surveys over the shelf and slope off Oregon and Washington, one Steller sea lion was seen on the Oregon shelf during January 2011, and two sightings totaling eight individuals were made on September 2012 off southern Oregon (Adams et al. 2014). During a survey off Washington/Oregon June–July 2012, two Steller sea lions were seen from R/V *Langseth* (RPS 2012b) off southern Oregon. Eight sightings of 11 individuals were made from R//V *Northern Light* during a survey off southern Washington during July 2012 (RPS 2012a). Steller sea lions were also taken as bycatch off southern Oregon in the west coast groundfish fishery during 2002–2009 (Jannot et al. 2011).

In B.C., there are six main rookeries, which are situated at the Scott Islands off northwestern Vancouver Island, the Kerouard Islands near Cape St. James at the southern end of Haida Gwaii, North Danger Rocks in eastern Hecate Strait, Virgin Rocks in eastern Queen Charlotte Sound, Garcin Rocks off southeastern Moresby Island in Haida Gwaii, and Gosling Rocks on the central mainland coast (Ford 2014). The Scott Islands and Cape St. James rookeries are the two largest breeding sites with 4000 and 850 pups born in 2010, respectively (Ford 2014). Some adults and juveniles are also found on sites known as year-round haulouts during the breeding season. Haul outs are located along the coasts of Haida Gwaii, the central and northern mainland coast, the west coast of Vancouver Island, and the Strait of Georgia; some are year-round sites whereas others are only winter haul outs (Ford 2014). Pitcher et al. (2007) reported 24 major haulout sites (>50 sea lions) in B.C., but there are currently around 30 (Ford 2014). The total pup and non-pup count of Steller sea lions in B.C. in 2002 was 15,438; this represents a minimum population estimate (Pitcher et al. 2007). The highest pup counts in B.C. occur in July (Bigg 1988). Steller sea lions could be encountered in the proposed project areas, especially in the waters closer to shore.

3.3.3.6 California Sea Lion (*Zalophus californianus*)

The primary range of the California sea lion includes the coastal areas and offshore islands of the eastern North Pacific Ocean from B.C. to central Mexico, including the Gulf of California (Jefferson et al. 2015). However, its distribution is expanding (Jefferson et al. 2015), and its secondary range extends into the Gulf of Alaska (Maniscalco et al. 2004) and southern Mexico (Gallo-Reynoso and Solórzano-Velasco 1991), where it is occasionally recorded.

California sea lion rookeries are on islands located in southern California, western Baja California, and the Gulf of California (Carretta et al. 2019). Five genetically distinct geographic populations have been identified: (1) Pacific Temperate (includes rookeries in U.S. waters and the Coronados Islands to the south), (2) Pacific Subtropical, (3) Southern Gulf of California, (4) Central Gulf of California, and (5) Northern

Gulf of California (Schramm et al. 2009). Animals from the Pacific Temperate population occur in the proposed project area.

In California and Baja California, births occur on land from mid-May to late-June. During August and September, after the mating season, the adult males migrate northward to feeding areas as far north as Washington (Puget Sound) and B.C. (Lowry et al. 1992). They remain there until spring (March–May), when they migrate back to the breeding colonies (Lowry et al. 1992; Weise et al. 2006). The distribution of immature California sea lions is less well known but some make northward migrations that are shorter in length than the migrations of adult males (Huber 1991). However, most immature seals are presumed to remain near the rookeries for most of the year, as are females and pups (Lowry et al. 1992).

California sea lions are coastal animals that often haul out on shore throughout the year, but peak numbers off Oregon and Washington occur during the fall (Bonnell et al. 1992). During aerial surveys off the coasts of Oregon and Washington during 1989–1990, California sea lions were sighted at sea during the fall and winter, but no sightings were made during June–August (Bonnell et al. 1992). Numbers off Oregon decrease during winter, as animals travel further north (Mate 1975 *in* Bonnell et al. 1992). King (1983) noted that sea lions are rarely found more than 16 km offshore. During fall and winter surveys off Oregon and Washington, mean distance from shore was ~13 km and most were observed in water <200 m deep; however, sightings were made in water as deep as 356 m (Bonnell et al. 1992). Weise et al. (2006) reported that males normally forage almost exclusively over the continental shelf, but during anomalous climatic conditions they can forage farther out to sea (up to 450 km offshore).

During aerial surveys over the shelf and slope off Oregon and Washington (Adams et al. 2014), California sea lions were seen during all survey months (January–February, June–July, September–October). Although most sightings occurred on the shelf, during February 2012, one sighting was made near the 2000-m depth contour, and during June 2011 and July 2012, sightings were made along the 200-m isobath off southern Oregon (Adams et al. 2014). During October 2011, sightings were made off the Columbia River estuary near the 200-m isopleth and on the southern Oregon shelf; during September 2012, sightings occurred in nearshore waters off Washington and in shelf waters along the coast of Oregon (Adams et al. 2014). Adams et al. (2014) reported sightings more than 60 km off the coast of Oregon. California sea lions were also taken as bycatch off Washington and Oregon in the west coast groundfish fishery during 2002–2009 (Jannot et al. 2011).

California sea lions used to be rare in B.C., but their numbers have increased substantially during the 1970s and 1980s (Ford 2014). Wintering California sea lion numbers have increased off southern Vancouver Island since the 1970s, likely as a result of the increasing California breeding population (Olesiuk and Bigg 1984). Several thousand occur in the waters of B.C. from fall to spring (Ford 2014). Adult and subadult male California sea lions are mainly seen in B.C. during the winter (Olesiuk and Bigg 1984). They are mostly seen off the west coast of Vancouver Island and in the Strait of Georgia, but they are also known to haul out along the coasts of Haida Gwaii, including Dixon Entrance, and the mainland (Ford 2014). California sea lions could be encountered in the proposed project area.

3.3.4 Fissiped

3.3.4.1 Northern Sea Otter (*Enhydra lutris kenyoni*)

The northern sea otter can be found along the coast of North America from Alaska to Washington. Sea otters generally occur in shallow (<35 m), nearshore waters in areas with sandy or rocky bottoms, where they feed on a wide variety of sessile and slow-moving benthic invertebrates (Rotterman and Simon-Jackson 1988). Sea otters are generally not migratory and do not disperse over long distances; however, individual sea otters are capable of travelling in excess of 100 km (Garshelis and Garshelis 1984), although movements are likely limited by geographic barriers, high energy requirements of animals, and social behavior. Before commercial exploitation, the worldwide population of sea otters was estimated to be between 150,000 (Kenyon 1969) and 300,000 (Johnson 1982). Commercial exploitation reduced the total sea otter population to as low as 2000 in 13 locations (Kenyon 1969). In 1911, sea otters received protection under the North Pacific Fur Seal Convention, and populations recovered quickly (Kenyon 1969). The world sea otter population is currently estimated at ~150,000 (Davis et al. 2019).

Sea otters were translocated from Alaska to shallow coastal waters off the Olympic Peninsula of Washington; the population has increased from 59 reintroduced individuals in 1969–1970 to ~2058 in 2017 (Sato et al. 2018). The population ranges from Pillar Point in the Strait of Juan de Fuca to Cape Flattery, and south to Point Grenville (USFWS 2018). Although sea otters were also reintroduced to Oregon in the 1970s, the reintroduction was not successful (McAllister 2018). Sightings in Oregon are extralimital (Jeffries et al. 2019), and there is no resident sea otter population along the Oregon coast (Kone 2019). Nonetheless, at times sea otters are reported as far south as Newport, Depoe Bay, Yaquina Head, Cape Blanco, and Cape Arago, and Yaquina Head (USFWS 2018; Elakha Alliance 2020).

Sea otters occur in coastal areas of Washington typically in shallow (<30 m depth) water less than 4 km from shore (Laidre et al. 2009).

Sea otters were also translocated from Alaska to B.C. (Bigg and MacAskie 1978). In 2013, the B.C. population was estimated to number at least 6754 individuals (DFO 2015a; Nichol et al. 2015). In B.C., sea otters regularly occur off northern and western Vancouver Island, and along the central mainland coast (Ford 2014; DFO 2015a; Nichol et al. 2015). Although most individuals occur north of Clayoquot Sound (Nichol et al. 2015), some animals occur in Barkley Sound and in the Strait of Juan de Fuca to Victoria (Ford 2014). There is some limited interchange between sea otter populations in Washington and B.C. (USWFS 2018). Given that the survey is proposed to occur in water >60 m, sea otters are not expected to occur within the harassment zone of the airgun array

3.4 Sea Turtles

Four species of sea turtles have been reported in the waters of B.C., Washington, and Oregon: the leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*), loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) turtles (McAlpine et al. 2004; CBC 2011a,b; Halpin et al. 2018). Reports of leatherbacks are numerous, and green turtles have been seen occasionally in the survey area compared to occurrences of loggerhead and olive ridley turtles, which are rare. In B.C., there is a single record for the loggerhead (Halpin et al. 2018) and four records of olive ridley turtles, with the most recent one reported on 30 September 2019 (The Marine Detective 2019). The loggerhead was spotted ~45 n.mi. west of Tofino in February 2015.

All four species of turtles have also been documented off the coasts of Oregon and Washington (Buchanan et al. 2001; Dutton et al. 2009). However, green, loggerhead, and olive ridley sea turtles are considered accidental in Oregon (ODFW 2013). For Oregon, there are two occurrences of loggerheads from 2007–2017, and at least seven occurrences of olive ridleys from 2010–2018 (Oregonian 2012; Oregon Coast Aquarium 2019). Strandings have increased in recent years, particularly for olive ridley sea turtles, possibly due to warmer ocean conditions or El Niño (Boyer 2017). For Washington, there are eight records of loggerhead turtles from 1980–2017 (the most recent occurrence was November 2010; Sato 2017a) and few records of olive ridleys (e.g., Richardson 1997; Komo News 2015; Seattle Times 2017). However, the loggerhead and olive ridley turtles are generally warm-water species and are considered extralimital occurrences in these areas (Buchanan et al. 2001) and are not discussed further here. Thus, only leatherback turtles are likely to occur in the survey area, and green turtles could potentially occur there.

Under the ESA, the leatherback turtle and the North Pacific Ocean DPS of the loggerhead turtle are listed as ***endangered***, the olive ridley population on the Pacific coast of Mexico is listed as ***endangered*** whereas other populations are listed as ***threatened***, and the East Pacific DPS of the green turtle is listed as ***threatened***. The leatherback turtle is also listed as endangered under SARA; the other turtle species are not listed. General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of sea turtles are given in § 3.4.1 of the PEIS. General distribution of sea turtles off B.C. and just south of the survey area off California are discussed in § 3.4.3.2 and 3.4.2.3 of the PEIS, respectively. The rest of this section deals specifically with their distribution within the proposed survey area in the Northeast Pacific Ocean.

3.4.1 Leatherback Turtle (*Dermochelys coriacea*)

The leatherback is the largest and most widely distributed sea turtle, ranging far from its tropical and subtropical breeding grounds to feed (Plotkin 2003). There have been significant declines and some extirpations of nesting populations in the Pacific (Spotila et al. 2000; Dutton et al. 2007). Leatherback turtles in the Pacific are divided into two genetically distinct stocks: the East Pacific stock nests at rookeries along the west coast of the Americas from Mexico to Ecuador; and the West Pacific stock nests at rookeries in Papua, Indonesia; Papua New Guinea; and the Solomon Islands (Dutton 2006; Wallace and Hutchinson 2016). The beaches of Birdshead Peninsula in Papua are the largest remaining nesting sites for leatherbacks in the Pacific Ocean (Dutton et al. 2007; Hitipeuw et al. 2007; Benson et al. 2008). Turtles that hatch during the boreal summer in the western Pacific feed and grow in the northern Pacific, including along the west coast of North America (Dutton 2006; Dutton et al. 2009; Benson 2012; Bailey et al. 2012a; Wallace and Hutchinson 2016). The West Pacific subpopulation has declined by 83% over the past three generations and continues to be threatened by human exploitation of females and eggs, low hatching success, fisheries bycatch, low foraging success, and plastic ingestion (Bailey et al. 2012b; Gregr et al. 2015; Wallace and Hutchinson 2016). Nesting beaches in the western Pacific have been estimated to have 2700–4500 breeding females (NMFS and USFWS 2013).

The leatherback turtle is the most widely distributed sea turtle, occurring from 71°N to 47°S (Eckert et al. 2012). During the non-breeding season, it ranges far from its tropical and subtropical nesting grounds, which are located between 38°N and 34°S (Dutton et al. 2009; Eckert et al. 2012). Leatherbacks feed exclusively on gelatinous zooplankton (Fossette et al. 2010, 2012; Dodge et al. 2011; Heaslip et al. 2012) and their presence has been associated with oceanic front systems, such as shelf breaks and the edges of oceanic gyre systems where their prey is concentrated (Morreale et al. 1994; Eckert 1995; Lutcavage 1996; Benson et al. 2011).

Adult leatherbacks appear to migrate along bathymetric contours from 200–3500 m (Morreale et al. 1994). Adults spend the majority of their time in water >1000 m deep and possibly swim more than 10,000 km each year (Eckert 1995). They appear to use the Kuroshio Extension during migrations from Indonesia to the high seas and eastern Pacific (Benson et al. 2008). Hatchling leatherbacks are pelagic, but nothing is known about their distribution for the first four years (Musick and Limpus 1997). Leatherback turtles undertake long migrations from the western, central, or South Pacific toward the California Current LME (Block et al. 2011; Bailey et al. 2012a,b). Frair et al. (1972) and Greer et al. (1973) reported that leatherback turtles have evolved physiological and anatomical adaptations to cold water, allowing them to venture into higher latitudes than other species of turtle.

Leatherbacks forage in pelagic and nearshore waters off the coasts of Washington, Oregon and California during the summer and fall when brown sea nettles (*Chrysaora fuscescens*) and moon jellies (*Aurelia labiata*) aggregate (Sato 2017b). Benson et al. (2011) identified the Columbia River Plume as an important foraging area off southern Washington/northern Oregon. Leatherback turtles satellite-tagged at western Pacific nesting beaches were observed to arrive along the coasts of California to Washington during April–July, and foraging behavior was recorded through late November (Benson et al. 2011). In Washington, 78 occurrences of leatherbacks were documented during 1975–2013 from the mouth of the Columbia River north to Cape Flattery; 70 occurrences occurred during July–October (Sato 2017b). Aerial surveys of California/Oregon/Washington waters suggest that most leatherbacks occur in continental slope waters and fewer occur over the continental shelf. Sightings off Oregon/Washington have been made 8–149 km offshore (Green et al. 1992, 1993; Bowlby et al. 1994; Buchanan et al. 2001). Bowlby et al. (1994) noted that most sightings (13 of 19) during their surveys occurred in waters 200–2000 m deep, with one sighting in waters >2000 m deep.

In B.C., leatherbacks are considered an "uncommon seasonal resident" (McAlpine et al. 2004), and the size of the population that forages there seasonally is not known (COSEWIC 2012). Leatherbacks have been sighted off B.C. in all months except December and January, with a peak during late spring to early-fall when sea surface temperatures are highest (MacAskie and Forrester 1962; Spaven et al. 2009). Sightings of leatherbacks have been made throughout the waters of B.C., including offshore of Vancouver Island (McAlpine et al. 2004; Pacific leatherback Turtle Recovery Team 2006; Spaven et al. 2009; Holst 2017; CBC 2018b). Seventy-seven of the 118 sightings summarized by Spaven et al (2009) occurred along the south coast of B.C.; most of these overlap with the proposed survey area and were recorded during July–September. The majority of sightings in B.C. have been made in coastal waters, although turtles have also been sighted farther offshore in water >2000 m deep (Spaven et al. 2009; Holst 2017). In the absence of direct observations of leatherback foraging in Pacific Canadian waters, critical feeding habitat along the Pacific coast of Canada was modelled based on habitat preferences inferred from limited sightings data and was predicted to predominantly occur along the west coast of Vancouver Island (Gregr et al. 2015). Leatherback turtles could be encountered in the proposed project area.

3.4.2 Green Turtle (*Chelonia mydas*)

The green turtle is widely distributed in tropical, subtropical, and to a lesser extent, temperate waters, where it often occurs along continental coasts and around islands (SWOT 2011; Seminoff et al. 2015). Green turtles typically migrate along coastal routes from rookeries to feeding grounds, although some populations conduct trans-oceanic migrations (SWOT 2011). Hatchlings are epipelagic (surface dwelling in the open sea) for ~1–3 years. Subsequently, they live in bays and along protected shorelines and feed during the day on seagrass and algae (Bjorndal 1982). Juvenile and sub-adult green turtles may travel thousands of kilometers before they return to breeding and nesting grounds (Carr et al. 1978). Though primarily known to forage in coastal areas, adult green turtles have also been recorded feeding in oceanic waters (Hatase et al. 2006).

Movement of green turtles across the Pacific appears to be restricted by the East Pacific Barrier; thus only turtles from the East Pacific DPS are expected to occur in the eastern Pacific (Seminoff et al. 2015). The East Pacific DPS is estimated at 20,062 nesting females, ~58% of which nest in Michoacán, Mexico, and the population is likely to increase (Seminoff et al. 2015). Nesting occurs in Michoacán from August–January, with a peak in October–November (Alvarado and Figueroa 1995).

Stinson (1984) reviewed sea turtle sighting records from northern Baja California to Alaska, and reported only three sightings each of green turtles for Oregon, Washington, and B.C., and two sightings for

Alaska; most sightings occurred in California (78%). Green turtles are considered rare in Washington, where 28 occurrences, mostly strandings, were documented between 1950 and 2017; the most recent occurrence was in November 2010 (Sato 2017a). There are at least three occurrences for Oregon from 2010–2017 (Oregonian 2012; Oregon Coast Aquarium 2019).

Green turtles are also considered rare vagrants in B.C. waters (McAlpine et al. 2004). Most records of green turtles in B.C. have been of stranded carcasses, often relatively fresh, discovered from November–January (McAlpine et al. 2004). Two of the six records listed in McAlpine et al. (2004) occurred in the study area off the coast of Vancouver Island. Three live green turtles have recently washed ashore on Vancouver Island, all in the vicinity of the study area (CBC 2011b, 2016). A questionnaire that was sent out to commercial fisherman in 2003 reported 14 sightings of green turtles for B.C. (Spaven 2009). It is possible although unlikely that a green turtle would be encountered in the proposed project area.

3.5 Seabirds

Four seabird species that are listed as threatened or endangered under the ESA or SARA could occur in or near the proposed survey area. The short-tailed albatross (*Phoebastria albatrus*) is listed as ***endangered*** under the ESA and SARA, the Hawaiian petrel (*Phoebastria albatrus*) is listed as ***endangered*** under the ESA (no SARA listing), the pink-footed shearwater (*Puffinus creatopus*) is listed as *endangered* under SARA (no ESA listing), and the marbled murrelet (*Brachyramphus marmoratus*) is listed as ***threatened*** under the ESA and SARA. Critical habitat has been designated for the marbled murrelet in Canada and in the US from Washington to California. An additional ESA-listed species, the western snowy plover (*Charadrius nivosus nivosus*), would be present on shorelines adjacent to proposed survey area, but does not occur in pelagic habitats, so it is not discussed further.

In addition to the above species, there are six species listed as *special concern* under SARA which may be encountered in the survey area. These include the offshore black-footed albatross (*Phoebastria nigripes*), Cassin's auklet (*Ptychoramphus aleuticus*), ancient murrelet (*Synthliboramphus antiquus*), nearshore horned grebe (*Podiceps auratus*), and western grebe (*Aechmophorus occidentalis*); and the red-necked phalarope (*Phalaropus lobatus*) which occurs in offshore as well as nearshore locations. In addition, both the horned puffin (*Fratercula corniculate*) and common murre (*Uria aalge*) are considered candidates for endangered or threatened status in B.C. (B.C. CDC 2019) and could also occur within the survey area.

3.5.1 Short-tailed Albatross

Historically, millions of short-tailed albatrosses bred in the western North Pacific on islands off the coast of Japan (USFWS 2008). This species was the most abundant albatross in the North Pacific. However, the entire global population was nearly wiped out during the last century by feather hunters at Japanese breeding colonies. In addition to hunting pressures, the breeding grounds of the remaining birds were threatened by volcanic eruptions in the 1930s. This species was believed to be extinct by 1949; however, breeding was detected in 1950 and 1951, aided by pelagic-dwelling maturing birds which escaped the slaughter (USFWS 2008; BirdLife International 2019a). Due to conservation and management actions the population is increasing; the most recent population estimate is 4200 individuals (Birdlife International 2019a). Current threats to this population include volcanic activity on Torishima, commercial fisheries, and pollutants (USFWS 2008). Interactions with vessels in the eastern Pacific have been noted. Incidental take due to commercial fisheries has been documented, with one short-tailed albatross taken as bycatch off Oregon during the sablefish demersal fishery in 2011 (USFWS 2017), and 11 mortalities between 1995 and 2015 in the Alaska hook-and-line groundfish fishery (NMFS 2015b; USFWS 2017).

Currently, nearly all short-tailed albatrosses breed on two islands off the coast of Japan: Torishima and Minami-kojima (USFWS 2008; BirdLife International 2019a). Single nests have been found in recent years on other islands, including Kita-Kojima, Senkaku; Yomejima Island; and Midway Island, Hawaii; however, nesting attempts in Hawaii have not been successful (USFWS 2008). During the breeding season (December–May), the highest densities are found around Japan (BirdLife International 2019a), with albatross being seen as far south (23°N) as the Northwestern Hawaiian Islands between November and April (USFWS 2008).

During the non-breeding season, short-tailed albatross roam much of the North Pacific Ocean; females spend more time offshore from Japan and Russia, whereas males and juveniles spend more time around the Aleutian Islands and Bering Sea (Suryan et al. 2007). Post-breeding dispersal occurs from April through August (USFWS 2008). After leaving the breeding areas, short-tailed albatrosses seem to spend the majority of time within the EEZs of Japan, Russia, and the U.S., primarily in the Aleutian Islands and Bering Sea (Suryan et al. 2007). They are considered a continental shelf-edge specialist (Piatt et al. 2006). Most short-tailed albatross sightings off the Pacific coast of North America (south to California) are juveniles and sub-adults (USFWS 2008; O'Connor 2013). Satellite-tracked first- and second-year birds were found in Oregon waters most often during winter and spring, possibly in response to ice conditions in the Bering Sea (O'Connor 2013). Sightings in the eastern North Pacific are increasing, corresponding with global population increases (COSEWIC 2013a). The short-tailed albatross could be encountered in small numbers in the proposed project area.

3.5.2 Hawaiian Petrel

The Hawaiian petrel has an estimated population size of 6000–11,000 (Birdlife International 2019b). Large declines in overall numbers and in the number of breeding colonies appear to pre-date European arrival on the Hawaiian Islands, tracing back to animal introductions, habitat modifications, and hunting by Polynesians (Simons and Hodges 1998). The population of Hawaiian petrels continues to decline, mainly because of predation by introduced vertebrates, including mongooses, cats, and goats, and due to collisions and light attraction (USFWS 2005; Raine et al. 2017).

The Hawaiian petrel is endemic to Hawaii, where it nests at high elevation. Known nesting habitats include lava cavities, burrows on cliff faces or steep slopes, and beneath ferns (USFWS 2005). The majority of eggs are laid in May and June, and most young fledge in December (Mitchell et al. 2005). Hawaiian petrels can travel up to 1300 km away from colonies during foraging trips; at-sea densities decrease with distance from the colony (Spear et al. 1995). Spear et al. (1995) showed the distribution of Hawaiian petrels to be concentrated in the southern portion of the Main Hawaiian Islands (below 20°N) during spring and autumn. However, in recent years, the Hawaiian petrel has been recognized to be a regularly occurring offshore species to the eastern Pacific in waters from southern California to B.C. In California, where observer coverage is perhaps highest, there are records from March through September (eBird 2019). There are two accepted records of Hawaiian petrel in Washington (September 2008 and May 2014; WBRC 2018) and three in B.C. (July 2013, May 2014, and July 2014; BCBRC 2018), although occurrences are likely more frequent than observations suggest owing to the minimal observer coverage at the distance from shore which these petrels typically frequent. The Hawaiian petrel could be encountered in small numbers in the proposed project area, but is more likely to occur along the southern transects.

3.5.3 Marbled Murrelet

Marbled murrelets are widespread along the Pacific coast and are generally found in nearshore waters, usually within 5 km of shore (Nelson 1997). The population(s) of marbled murrelets in California, Oregon, and Washington has declined by nearly 30% from 23,700 individuals in 2000 to 16,700 individuals in 2010 (Miller et al. 2012). The primary reason for declining populations is the fragmentation and destruction of old-growth forest nesting habitat. Marbled murrelets are also threatened by gillnet fishing, nest predation, and oil spills.

Nesting critical habitat for marbled murrelets consists of forest stands containing large trees with potential nest platforms (including large branches, deformities, mistletoe infestations) at least 10 m in height; high canopy cover is also important for nesting murrelets (USFWS 2016b). Although terrestrial critical habitat has been identified in B.C., Washington, and Oregon, no critical marine habitat has been designated for marbled murrelets to date, although it could be identified in B.C. in the future (B.C. Government 2018). Marbled murrelet nesting occurs between late March and August, but the birds remain in the waters of that region during the non-breeding season.

Marbled murrelets feed at sea where they forage on small schooling fish and invertebrates in bays and fiords and in the open ocean (Nelson 1997). Feeding habitat for marbled murrelets is mostly within 2 km of shore in waters up to 30 m deep (USFWS 2006). Although they have been observed more than 40 km from shore in water deeper than 200 m (Adams et al. 2014), the mean offshore distance over a 3-year tracking study was 1.4 km (Hébert and Golightly 2008). Marbled murrelets are unlikely to occur in the offshore waters of the proposed study area; however, they can be expected on survey transects that approach within a few kilometers from shore.

3.5.4 Pink-footed Shearwater

The pink-footed shearwater is mostly found in the eastern Pacific from Chile north to Alaska, but only breeds on three islands off the coast of Chile (CEC 2005). On the breeding islands of Isla Mocha, Robinson Crusoe and Santa Clara, pink-footed shearwater populations have declined due to increased nest predation from introduced predators and humans, human disturbance, and habitat degradation (CEC 2005). The total global population is estimated at about 28,000 breeding pairs, plus non-breeders (COSEWIC 2016b), or about 59,000 individuals (BirdLife International 2019c). It has been estimated that up to 20,000 pink-footed shearwaters use B.C. waters annually (COSEWIC 2016b), a potentially significant portion of the total population.

Pink-footed shearwaters are found in continental shelf (to the 200 m isobath), shelf-break, and continental slope (between the 200 and 500 m isobaths) waters of the eastern Pacific (COSEWIC 2016b). They occur off the North American coast during the northern spring, summer, and autumn, with birds returning southwards in October and November to breed off Chile (CEC 2005). Off the B.C. coast, pink-footed shearwaters are regular summer visitors, with numbers peaking in June–October (COSEWIC 2016b). Pink-footed shearwaters could be encountered within the proposed survey area.

3.6 Fish and Marine Invertebrates, Essential Fish Habitat, and Habitat Areas of Particular Concern

3.6.1 ESA-Listed Fish Species

The term "species" under the ESA includes species, subspecies, and, for vertebrates only, DPSs or "evolutionarily significant units (ESUs)"; for Pacific salmon, ESUs are essentially equivalent to DPSs for the purpose of the ESA. There are several ESA-listed fish species or populations that occur off the coasts of Washington/Oregon including the ESUs of chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), coho (*O. kisutch*), and sockeye salmon (*O. nerka*), and DPSs of steelhead (Oncorhynchus mykiss), bull trout (*Salvelinus confluentus*), bocaccio (*Sebastes paucispinis*), yellow-eye rockfish (*S. ruberrimus*), Pacific eulachon (*Thaleichthys pacificus*), and green sturgeon (*Acipenser medirostris*) (Table 6).

TABLE 6. Fish "species" listed under the ESA that could occur in the proposed survey area off Washington and Oregon (NOAA 2019d).

Species	ESU or DPS	Status	Critical Habitat
Bocaccio	Puget Sound/Georgia Basin DPS	Endangered	Marine
Yelloweye Rockfish	Puget Sound/Georgia Basin DPS	Threatened	Marine
Pacific eulachon/smelt	Southern DPS	Threatened	Freshwater/estuarine
Green sturgeon	Southern DPS	Threatened	Marine/freshwater/estuarine
Chinook salmon	Sacramento River winter-run ESU	Endangered	Freshwater
	Upper Columbia River spring-run ESU	Endangered	Freshwater
	California Coastal ESU	Threatened	Freshwater
	Central Valley spring-run ESU	Threatened	Freshwater
	Lower Columbia River ESU	Threatened	Freshwater
	Puget Sound ESU	Threatened	Freshwater/marine
	Snake River fall-run ESU	Threatened	Freshwater
	Snake River spring/summer-run ESU	Threatened	—
	Upper Willamette River ESU	Threatened	Freshwater
	Upper Klamath-Trinity River ESU	Candidate	—
Chum salmon	Columbia River ESU	Threatened	Freshwater
	Hood Canal summer-run ESU	Threatened	Freshwater/marine
Coho salmon	Central California Coast ESU	Endangered	—
	Lower Columbia River ESU	Threatened	Freshwater
	Oregon Coast ESU	Threatened	Freshwater
	S. Oregon and N. California coasts ESU	Threatened	—
Sockeye salmon	Ozette Lake ESU	Threatened	Freshwater
	Snake River ESU	Endangered	—
Steelhead trout	Northern California Summer Population DPS	Candidate	—
	Southern California DPS	Endangered	Freshwater
	California Central Valley DPS	Threatened	Freshwater
	Central California Coast DPS	Threatened	Freshwater
	Northern California DPS	Threatened	Freshwater
	South-Central California Coast DPS	Threatened	Freshwater
	Lower Columbia River DPS	Threatened	Freshwater
	Middle Columbia River DPS	Threatened	Freshwater
	Puget Sound DPS	Threatened	Freshwater
	Snake River Basin DPS	Threatened	Freshwater
	Upper Columbia River DPS	Threatened	Freshwater
	Upper Willamette River DPS	Threatened	Freshwater
Bull trout	Coastal-Puget Sound	Threatened	Freshwater

Although the ***threatened*** giant manta ray (*Manta birostris*) and oceanic whitetip shark (*Carcharhinus longimanus*), and the ***endangered*** Eastern Pacific DPS of scalloped hammerhead shark (*Sphyrna lewini*) occur in the Northeast Pacific Ocean, their most northerly extent is California. No ESA-listed marine invertebrate species occur in the proposed survey area.

3.6.1.1 Salmonids

Pacific salmon and steelhead trout typically spend the majority of their time in the upper water column while at sea (e.g., Daly et al. 2014; PFMC 2014). However, Chinook typically occur at depths >30 m from the sea surface (PFMC 2014). The degree to which Pacific salmon and steelhead migrate offshore varies considerably among seasons, years, life stages and/or populations, with stronger upwelling conditions generally leading to wider dispersal from shore (Pearcy 1992). Tag recoveries from high seas fisheries indicate that chinook occur beyond the shelf break (Myers et al. 1996). Once coho salmon emigrate from freshwater, they spend at least several weeks and up to a summer season in coastal waters before migrating north and offshore (PFMC 2014). Tag recoveries from fisheries indicate that coho are distributed as far west as 175ºE (Myers et al. 1996). However, the oceanic distribution of chum salmon is likely the broadest of any Pacific salmon species; it occurs throughout the North Pacific Ocean north of Oregon/Washington (Neave et al. 1976). Sockeye are thought to follow a similar migration pattern as chum once they enter the ocean, moving north and west along the coast before moving offshore (Quinn 2005; Byron and Burke 2014). Sockeye primarily occur east of 160ºW and north of 48ºN; most fish likely depart offshore waters by early August of their second at-sea year to spawn in their natal rivers (French et al. 1976). Steelhead appear to rely on offshore waters for feeding than any other Pacific salmonids, making more extensive migrations offshore in their first year (Quinn and Myers 2004). Light et al. (1989) found that steelhead is distributed throughout the North Pacific year-round, occurring in higher abundance closer to the coasts during spring and winter and being distributed more evenly during summer and autumn.

The Coastal-Puget Sound DPS of bull trout is the only known anadromous population in U.S. waters, occurring throughout Puget Sound and the Olympic Peninsula south to the Quinault River Estuary. Bull trout have not been detected to use deep offshore waters or cross deep open-water bodies (e.g., coastal cutthroat trout) and appear to occupy marine waters for a shorter period of time than other anadromous salmonids (Goetz et al. 2013). Juveniles, sub-adults and adults generally occupy marine waters from early spring (March) to summer (late July), but some are known to overwinter in coastal waters. Fish that were radio-tagged in Skagit River in March and April 2006 entered Skagit Bay from March to May and returned upstream from May to late July (Hayes et al. 2011). Saltwater residency of these fish ranged from 36 to 133 days (avg. 75 days), and most were detected less than 14 km (avg. 8.5 km) from the Skagit River. These bull trout were associated with the shoreline and stayed an average of 0.32 +/- 0.27 km from shore and occupied shallow waters <4 m deep. However, Smith and Huff (2020) detected a tagged bull trout up to 10 km from shore. Goetz (2016) reported that marine residence averaged 62.8 days (SD=37.6 days) but ranged from four days to a maximum of four months.

3.6.1.2 Bocaccio

Bocaccio are distributed in coastal waters over rocky bottoms from the Gulf of Alaska to Baja California, Mexico down to depths of 478 m, but are most common between 50–250 m (NMFS 2008b). Larval and pelagic juvenile bocaccio tend to occur within surficial waters and have been found as far as 480 km offshore the west coast (NMFS 2014). According to COSEWIC (2013b), here are only two demographic clusters of bocaccio, and the B.C. population likely overlaps with U.S. populations centered on the central and southern coasts of California Bocaccio are most common from Oregon to California, and genetic analysis suggests three population regions including Haida Gwaii, Vancouver Island to Point Conception, and southwards of Point Conception (NMFS 2008b). Bocaccio are bycaught in commercial groundfish fisheries in B.C., and population biomass has declined by over 90% since the 1950s, and by 28% since 2002, with no signs of recovery (COSEWIC 2013b).

3.6.1.3 Yelloweye Rockfish

Yelloweye rockfish are found in coastal waters from the Alaskan Aleutian Islands down to Baja California. They are found in depths ranging from 15–549 m over hard, complex bottoms but are most common in waters 91–180 m (COSEWIC 2008; NMFS 2008b). COSEWIC (2008) divided the population into two Designatable Units (DUs) of "inside" and "outside" populations. The inside DU includes the Strait of Georgia, Johnstone Strait, and the Queen Charlotte Strait, and the outside DU includes waters from southwest Alaska to northern Oregon, including offshore B.C. and the north and central coast waters

(COSEWIC 2008). Yelloweye rockfish are exceptionally long-lived and individuals have been aged at 115 years in B.C. (COSEWIC 2008). Yelloweye rockfish are caught commercially in groundfish trawls and recreationally by hook and line.

3.6.1.4 Eulachon

Eulachon are a small species of smelt that spend 95% of their lives in the marine environment, migrating to freshwater rivers to spawn. Their marine range extends from the Bering Sea to California, and three DUs have been identified that include the Central Pacific Coast, Nass/Skeena Rivers, and the Fraser River (COSEWIC 2011). Eulachon spawn after three years, typically in coastal rivers that are associated with glaciers or snowpacks (COSEWIC 2011). To date, eulachon have been reported to spawn in at least 40 rivers in B.C. (Schweigert et al. 2012). Eulachon have an exceptionally high lipid content (approximately 20%) and are an important species in FSC fisheries (Schweigert et al. 2012). In B.C., eulachon are bycaught in commercial groundfish and shrimp trawls and in pelagic hake nets; however, there is no targeted commercial or recreational fishery (COSEWIC 2011). However, they are taken commercially in Oregon (NOAA 2019g) and Washington (NMFS 2017).

3.6.1.5 Green Sturgeon

The green sturgeon is distributed from Alaska to California primarily in marine waters up to 110 m deep, migrating to freshwater during the spawning season. It is found from Grave Harbor, AK, and along the entire coast of B.C. during the spring and winter months. Green sturgeon have been identified in large concentrations near Brooks Peninsula off the northwestern Vancouver Island during May–June and October–November (DFO 2019c). During spawning season in the summer and fall, aggregations of green sturgeon are found in the Columbia River estuary, Willapa Bay, and Grays Harbor, WA, and in the Umpqua River estuary, OR (NMFS 2018b). The Rogue River, Klamath River, Eel River, Sacramento River, and Feather River have been confirmed as spawning rivers for green sturgeon in the U.S. (NMFS 2018b). There are no documented spawning rivers in Canada (COSEWIC 2004; DFO 2019c). There are currently no directed fisheries for green sturgeon (DFO 2019c; NOAA 2019g); however, adults are bycaught in commercial groundfish trawls and in recreational fisheries (DFO 2019c).

3.6.2 Essential Fish Habitat

Under the 1976 *Magnuson Fisheries Conservation and Management Act* (renamed *Magnuson Stevens Fisheries Conservation and Management Act* in 1996), Essential Fish Habitat (EFH) is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity". "Waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish. "Substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities (NOAA 2002). The *Magnuson Stevens Fishery Conservation and Management Act* (16 U.S.C.§1801–1882) established Regional Fishery Management Councils and mandated that Fishery Management Plans (FMPs) be developed to manage exploited fish and invertebrate species responsibly in federal waters of the U.S. When Congress reauthorized the act in 1996 as the *Sustainable Fisheries Act*, several reforms and changes were made. One change was to charge NMFS with designating and conserving EFH for species managed under existing FMPs. In Washington and Oregon, there are four FMPs covering groundfish, coastal pelagic species, highly migratory species, and Pacific salmon. The entire western seaboard from the coast to the limits of the EEZ is EFH for one or more species for which EFH has been designated. The proposed project area encompasses several EFHs (Fig. 3).

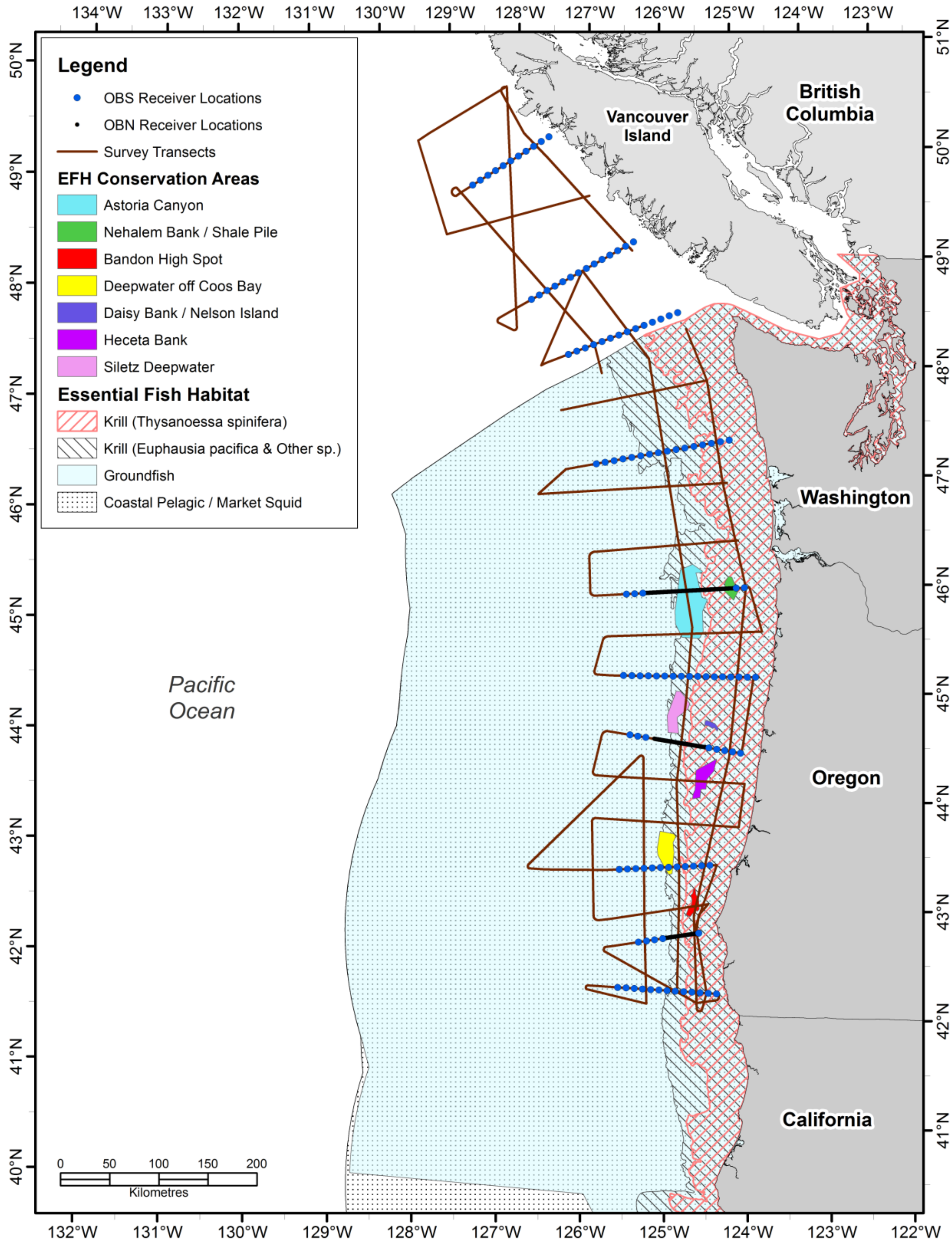

FIGURE 3. EFH in Washington and Oregon. Sources: NOAA 2018; NOAA WCR 2019; ODFW 2019b; USGS 2019.

Groundfish EFH.—The Pacific Coast Groundfish FMP manages more than 90 species (160 species/life stage combinations). The FMP provides a description of groundfish EFH for each of the species and their life stages (PFMC 2016a). When the EFH are taken together, the EFH for Pacific Coast groundfish includes all waters and substrate from the mean higher high water level or the upriver extent of saltwater intrusion along the coasts of Washington, Oregon, and California to within water depths <3500 m and seamounts in depths >3500 m (PMFC 2016a). In addition to the EFH parameters mentioned above, there are seven distinct EFH Conservation Areas within the proposed project area that are closed to bottom trawl fishing gear (Fig. 3) (NOAA 2018; NOAA WCR 2019; ODFW 2019b; USGS 2019).

Coastal Pelagic Species EFH.—The FMP for Pacific coast Coastal Pelagic Species (CPS) includes four finfish (Pacific sardine, Pacific [chub] mackerel, northern anchovy, and jack mackerel), market squid and all euphausiids (krill) species that occur in the west coast EEZ (PFMC 2016b). EFH for these species is defined both through geographic boundaries and by sea-surface temperature ranges. Because of similarities in their life histories and similarities in their habitat requirements, the four CPS finfish are treated as a single species complex for the purposes of EFH. Market squid are also treated in this same complex because they are similarly fished above spawning aggregations. The geographic boundary of EFH for CPS finfish and market squid is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the EEZ and above the thermocline where sea surface temperatures range between 10°C and 26°C; the southern extent of the EFH is the U.S.-Mexico boundary (see Fig. 3). The northern boundary of the range of CPS finfish is the position of the 10°C isotherm which varies both seasonally and annually (PFMC 2016b). EFH for krill (*Thysanoessa spinifera*) extends from the shoreline outwards to a depth of 1000 m, while EFH for *Euphausia pacifica* and other krill species in the area extends from the shoreline to ~2000-m depth (NOAA 2018).

Pacific Coast Salmon EFH.—The FMP for Pacific coast salmon includes the coast-wide aggregate of natural and hatchery salmon species that is contacted by salmon fisheries in the EEZ off the coasts of Washington, Oregon, and California (PFMC 2016c). The PFMC manages the fisheries for coho, chinook, and pink (odd-numbered years) salmon and has defined EFH for these three species. Pacific coast salmon EFH includes marine areas within the EEZ, from the extreme high tide line in nearshore and tidal submerged environments within state territorial waters out to the full extent of the EEZ, along with estuarine and all currently or historically occupied freshwater habitat within the internal waters of Washington, Oregon, Idaho, and California north of Point Conception (PFMC 2016c).

Highly Migratory Species EFH.—The FMP for the U.S. west coast fisheries for highly migratory species includes dorado/dolphinfish and important species of tunas (North Pacific albacore, yellowfin, bigeye, skipjack, and northern bluefin), billfish/swordfish (striped marlin and swordfish), and sharks (common thresher, shortfin mako/bonito and blue) which are harvested by west coast fisheries (PFMC 2016d). EFH for each life stage of these species is described in the FMP (PFMC 2016d); collectively the highly migratory species EFH extends outwards from near shore (~10 m water depth) to the limit of the EEZ off of Washington, Oregon, and California (NOAA 2018).

3.6.3 Habitat Areas of Particular Concern

Habitat Areas of Particular Concern (HAPCs) are a subset of EFH that provide important ecological functions, are especially vulnerable to degradation, or include habitat that is rare (NOAA 2019h). There are several HAPCs within or near the proposed survey area for groundfish (Fig. 4). There are no HAPCs designated at this time for highly migratory species (PFMC 2016d).

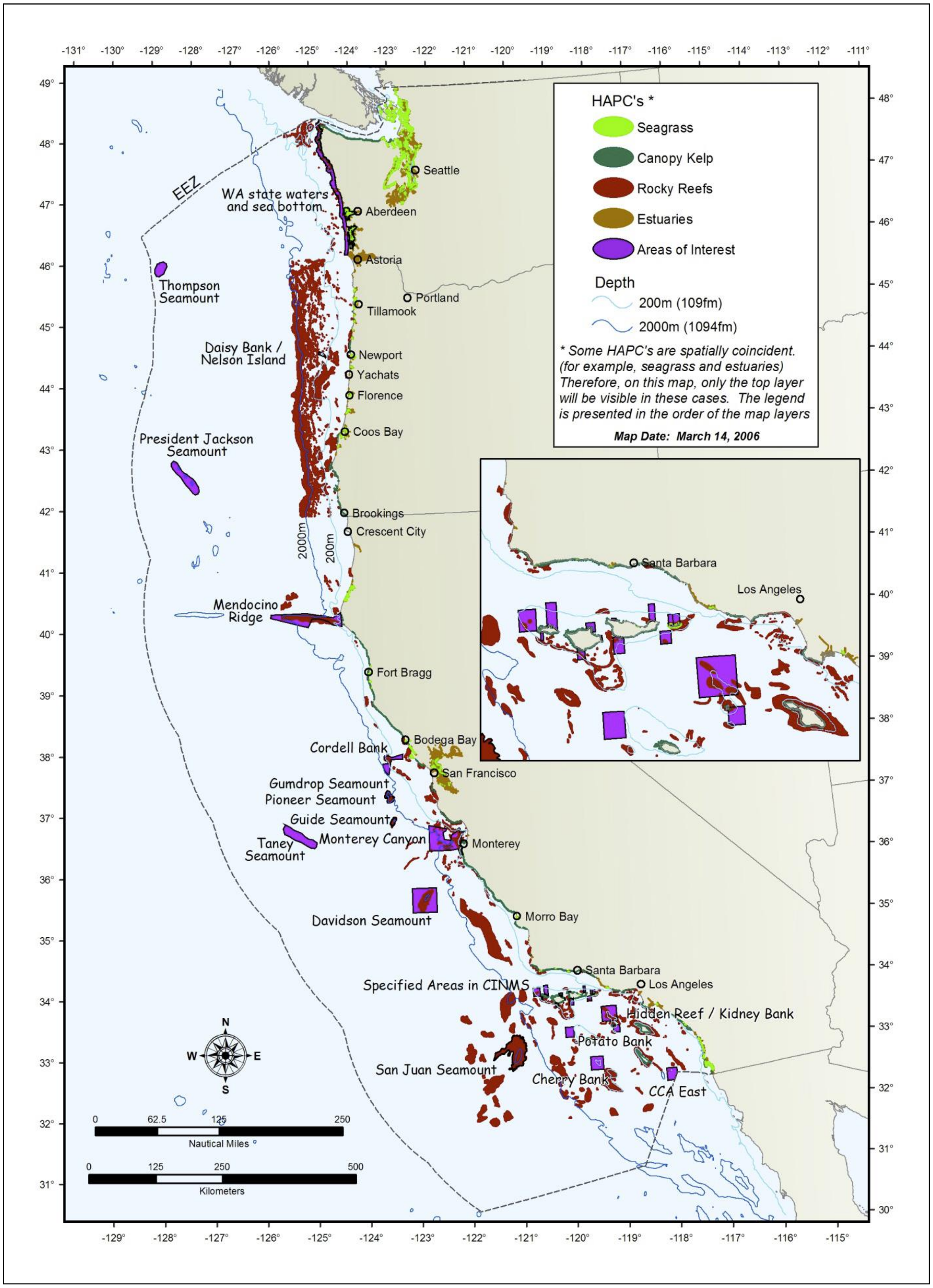

FIGURE 4. Groundfish HAPC in Washington, Oregon, and California. Source: PFMC (2016a).

Rocky Reefs HAPC.—The rocky reefs HAPC includes waters, substrates, and other biogenic features associated with hard substrate (bedrock, boulders, cobble, gravel, etc.) to mean higher high water level. The HAPC occurs primarily in Oregon waters 200–2000 m deep, including in the proposed survey area (see Fig. 4). The rocky reefs HAPC in Washington are mostly scattered in <200 m depth, including in the northern portion of the OCNMS (PFMC 2016a).

Daisy Bank/Nelson Island HAPC.—Daisy Bank area of interest HAPC is a highly unique geological feature that occurs in Federal waters west of Newport, Oregon (44°38'N) and appears to play a unique and potentially rare ecological role for groundfish and large invertebrate sponge species. The bank supports more than 600,000 juvenile rockfish per km^2. Daisy Bank also supports more and larger lingcod and large sponges than other nearby banks (*in* PFMC 2016a). It is located within the survey area (see Fig. 4).

Washington State Waters HAPC.—The Washington State Waters HAPC encompasses all waters and sea bottom in state waters shoreward from the 5.6 km boundary of the territorial sea shoreward to mean higher high-water level. The HAPC encompasses a variety of habitats important to groundfish, including other HAPCs such as rocky reef habitat supporting juvenile rockfish (primarily north of 47.2°N). Sandy substrates within state waters (primarily south of 47.2°N) are important habitat for juvenile flatfish. A large proportion of this area occurs within the OCNMS (PFMC 2016a). This HAPC is adjacent to the survey area (see Fig. 4).

Thompson and President Jackson Seamounts HAPC.—Seamounts have relatively high biodiversity; up to a third of species occurring on these features may be endemic (de Forges et al. 2000 *in* PFMC 2016a). Currents generated by seamounts retain rockfish larvae and zooplankton, a principal food source for rockfish (Genin et al. 1988, Mullineaux and Mills 1997, Haury et al. 2000, and Dower and Perry 2001 *in* PFMC 2016a). Deep-sea corals also occur on seamounts (Monterey Bay National Marine Sanctuary 2005 *in* PFMC 2016a). The Thompson Seamount HAPC has an area of ~430 km^2 and is closed to all bottom contact gear (Oren and DeVogelaere 2014). The HAPC is west of the survey area (see Fig. 4).

3.6.4 SARA-Listed Fish and Marine Invertebrate Species

There are two species that could occur within or near the survey area that are listed as *endangered* under SARA, including the basking shark and northern abalone (Table 7). However, northern abalone are not expected to occur in water deeper than 10 m and are not discussed further here; information regarding critical habitat was provided in Section 2.1.3. The *endangered* basking shark is the only SARA-listed fish species that could occur in the survey area. The Canadian Pacific population has been classified as *endangered* status under the SARA since 2010 and by COSEWIC since 2007 (DFO 2020b). In addition, several other fish species, as well as the Olympia oyster, are listed as *special concern*.

The basking shark is the second largest fish in the world reaching lengths of 12.2 m and an age of 50 years (DFO 2011b, 2020a). Basking sharks are slow to grow and mature, and exhibit low fecundity making them vulnerable to environmental change and anthropogenic threats. They are planktivorous and primarily filter-feed on copepod zooplankton in surface waters, where they spend ~19% of their time, along coastal shelf areas (DFO 2011b, 2020a). In Canadian Pacific waters, basking sharks are considered a migratory species that winter off California and spend the spring and summer months off B.C. (McFarlane et al. 2009 *in* DFO 2020b). Historically, basking sharks aggregated in large numbers ranging from the hundreds to the thousands in the Canadian Pacific; however, present populations may only number 321–535 individuals, and that estimate is uncertain (DFO 2020b). From 1996–2018, only 37 confirmed or reliable basking shark sightings were recorded in Canadian Pacific waters (DFO 2020b). The main threats posed to basking sharks are primarily anthropogenic and include net entanglement, collision with vessels, harassment from marine based activities, and prey availability. Historically, net entanglement, bycatch, sport harpooning, government eradication efforts (occurring from 1942–1969) and directed fisheries (during the 1920s and 1940s) were the cause of the dramatic population decline (DFO 2009, 2011b, 2020b).

3.6.5 Rockfish Conservation Areas

***Rockfish Conservation Areas*.—**RCAs were established in 2002 to alleviate rockfish population declines. RCAs are located in marine waters along the B.C. coast, including adjacent to the proposed survey area (Fig. 5). Inshore rockfish are protected from mortality associated with recreational and commercial fishing in the RCAs; in addition, fishery monitoring and stock assessment programs are conducted. There are 37 species of rockfish that are typically caught by hook and line in rocky reef habitat along the B.C. coast (DFO 2015b). Inshore rockfish are found at shallow depth, but may occur in water as deep as 600 m; they include yelloweye, quillback, *S. maliger*; copper, *S. caurinus*; china, *S. nebulosus*; and tiger rockfish, *S. nigrocinctus* (DFO 2018d). Shelf species (e.g., bank, *S. rufus*; canary; bocaccio) are typically found in intermediate depths, but also occur at depths up to 600 m (DFO 2018d). Slope species are found at depths of 100–2000 m, and include the Pacific Ocean perch, *S. alutus* (DFO 2018d). Although none of the rockfish species are listed as *endangered* or *threatened* under SARA, rougheye rockfish (e.g., *S. aleutianus*) and yelloweye rockfish are considered *special concern* (Table 7).

3.7 Fisheries

3.7.1 Commercial Fisheries

The commercial Oregon and Washington fisheries harvest at least 170 species, including fish such as salmon, rockfish, flatfish, sharks, and tuna; crustaceans; mollusks; and other invertebrates (NOAA 2019g; ODFW 2019c). The highest landings (in metric tons) occur during July and August (NOAA 2017). In order of descending catch weight, the primary fish species recorded during 2014 in the Oregon, Washington, and Vancouver Coast and Shelf Marine Ecoregion included North Pacific hake (583.19 t), shrimp (63.46 t), Pacific cupped oyster (55.53 t), dungeness crab (29.13 t), chum salmon (11.06 t), coho salmon (8.44 t), pink salmon (2.89 t), Alaska pollock (1.8 t), and redfishes (1.42 t). Other species accounted for 174.48 t of the total catch (Sea Around Us 2016a). North Pacific hake has been the primary species caught since the 1960s, dropping off between the 1980s and 1990s, but landings have steadily increased to present day levels (Sea Around Us 2016a). The most common gear type used in the ecoregion as well as in the U.S. west coast fishery in 2014 was pelagic trawls (Sea Around Us 2016a,b). In B.C., harvests for commercial pelagic species are primarily taken using mobile gear such as seines, gillnets, and trawls, and fixed gear such as longlines and traps, in addition to hand harvesting for bivalve species (DFO 2019b).

3.7.2 Recreational Fisheries

Most marine recreational fisheries on the U.S. west coast occur within non-federal (shore to 5.6 km off the coast) waters, but some effort also occurs in federal waters (5.6 km to the extent of the EEZ); anglers fish from shore, private boats, and commercial passenger fishing vessels (NOAA 2019i). Species typically taken during recreational fisheries on the west coast include highly migratory species (albacore and other tunas, striped marlin, common thresher shark, shortfin mako shark), salmon (Chinook, coho), steelhead, groundfish (rockfish, lingcod scorpionfish, greenling, flatfish, sharks), halibut, coastal pelagic species (Pacific sardine, northern anchovy, market squid, Pacific mackerel), various state-managed species (barracuda, bass, bonito, sturgeon, surfperches), and invertebrates (abalone, lobster, crab, clams, oysters) (NOAA 2019i). During 2016, 1.2 million anglers took 5.2 million saltwater fishing trips, supporting $3 billion in sales on the U.S. west coast (NOAA 2019i).

TABLE 7. Marine fishes that may occur within the study area identified as species at risk under SARA, and their status under COSEWIC and their spatial distribution. Currently, only those species on Schedule 1 of SARA and designated as endangered or threatened are afforded protection measures.

Species	***SARA*[1,2]**			**COSEWIC[1]**			**Water Depth Range[2]**	**Distributional Range[2]**
	E	**T**	**SC**	**E**	**T**	**SC**		
Marine Fish								
Basking Shark (*Cetorhinus maximus*) Pacific Ocean population	S1			X			1000	B.C. to California
Bluntnose Sixgill Shark (*Hexanchus griseus*) Pacific Ocean population			S1			X	2500	Pacific Coast including the Strait of Georgia
Green Sturgeon (*Acipenser medirostris*) Pacific Ocean population			S1			X	610	Alaska to Mexico
Longspine Thornyhead (*Sebastolobus altivelis*) Pacific Ocean population			S1			X	1600	Alaska to Baja California, Mexico
Rougheye Rockfish Type I and Type II (*Sebastes* sp.) Pacific Ocean population			S1			X	800	Alaska to southern California
Yelloweye Rockfish (*Sebastes ruberrimus*) Pacific Ocean Inside Waters population			S1			X	232	Strait of Georgia, Johnstone Strait, Queen Charlotte Strait
Pacific Ocean Outside Waters population			S1			X	232	Alaska to northern Oregon
Tope (*Galeorhinus galeus*) Pacific Ocean population			S1			X	471	Hecate Strait, B.C., to Gulf of California
Bull trout[3] (*Salvelinus confluentus*) South Coast B.C. population			S1			X	4	B.C. to Washington
Marine Invertebrates								
Northern Abalone (*Haliotis kamtschatkana*) Pacific Ocean population	S1			X			100	Alaska to Baja California, Mexico
Olympia Oyster (*Ostrea lurida*) Central Coast population			S1			X	50	Gale Passage, B.C., to Baja California, Mexico
Johnstone Strait population			S1			X	50	
Queen Charlotte population			S1			X	50	
Strait of Georgia population			S1			X	50	
Strait of Juan de Fuca population			S1			X	50	
West Coast Vancouver Island population			S1			X	50	

1 Government of Canada (2021d). E = Endangered; T = Threatened; SC = Special Concern; S1 = Schedule 1.
2 DFO (2019a).
3 Hayes et al. (2011).

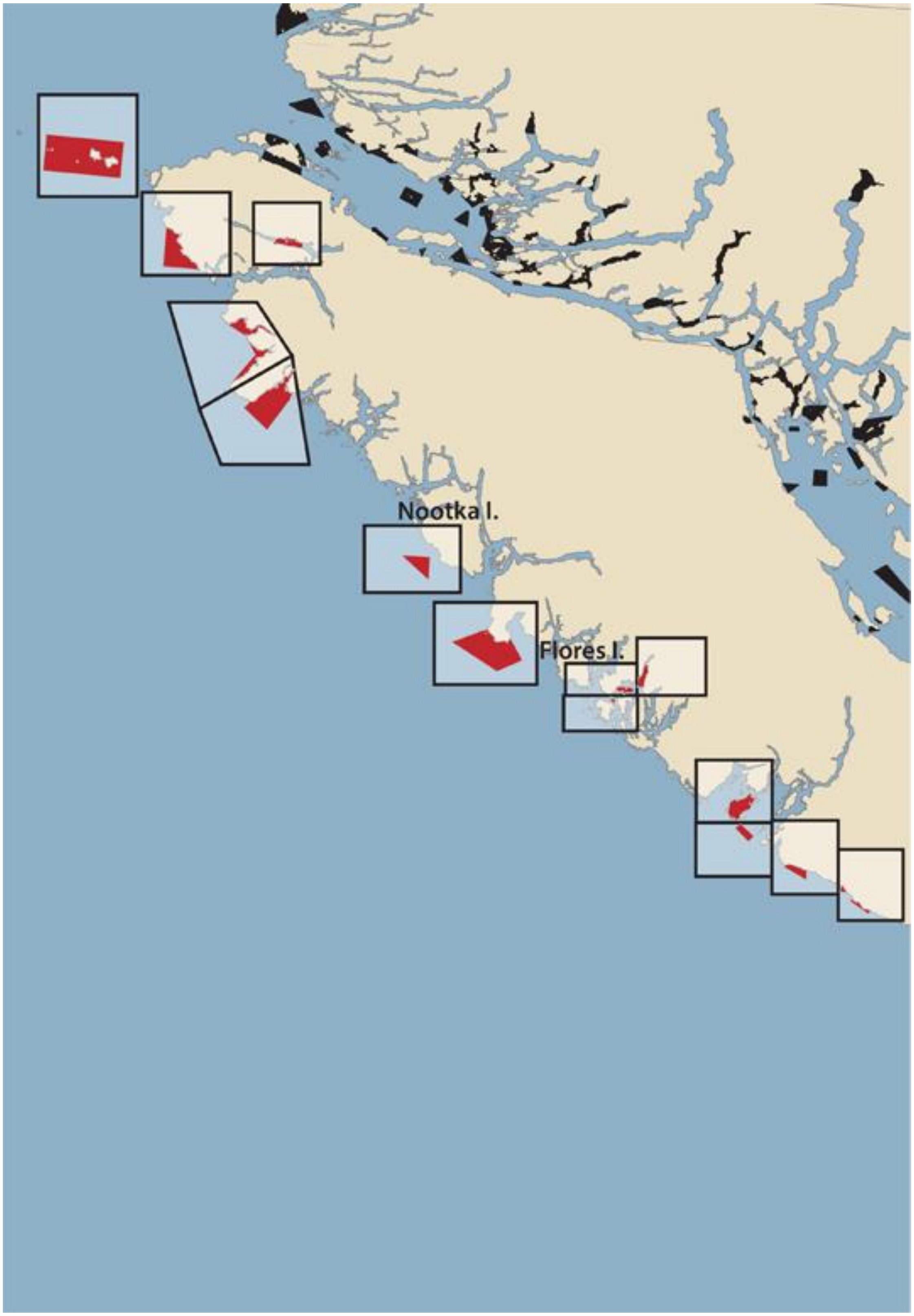

FIGURE 5. Rockfish Conservation Areas adjacent to the proposed project area. Source: DFO (2015b)

Recreational oceanic salmon fisheries off Oregon are open from March–November (location- and species-dependent); during 2018, there were 63,829 angler trips for this fishery (ODFW 2019d). Recreational groundfish taken off Oregon for which catch quotas are set include black rockfish, blue and deacon rockfishes, cabezon, canary rockfish, kelp and rock greenlings, "minor nearshore rockfishes" (China, copper, black-and-yellow, brown, calico, gopher, grass, kelp, olive, treefish, and quillback), and yelloweye rockfish; these species are primarily fished during spring and summer, with peak catches typically during July and August (ODFW 2019e). Pacific halibut are also caught during both nearshore and offshore recreational fisheries off Oregon, with the season running from May–October, with peak catches occurring from May–August (ODFW 2019f).

Recreational fisheries off Washington include salmon (Chinook, coho, chum, pink, sockeye, jacks), marine fish (bottomfish [e.g., rockfish, lingcod, sole, flounder], forage fish [e.g., herring, smelt], tunas and mackerels, Pacific halibut), and shellfish (e.g., clams, oysters, shrimp, crab) (Kraig and Scalici 2017). The recreational fishing season varies by species and location, but generally runs from May–October with peaks during mid-summer to early-fall (Kraig and Scalici 2017). The main species that contribute to the recreational fishery in B.C. include coho and chinook salmon, and Pacific halibut (MaPP 2015; DFO 2020c). Other finfish species are also caught recreationally, in addition to bivalves, crabs, and other invertebrates (DFO 2020c). In 2010, 1260 t were taken in the recreational fishery (Ainsworth 2015).

3.7.3 Tribal and First Nation Fisheries

The coast and nearshore areas are of cultural and economic importance to indigenous people of the Pacific Northwest. Since time immemorial, exercising fishing, hunting, and gathering for commercial, ceremonial, and subsistence purposes throughout the Pacific Northwest has been essential to Indigenous people in the region. Tribes in Washington State have treaties with the federal government that include fishing rights within "Usual and Accustomed Fishing and Hunting Areas" (U&A). These treaty rights have been confirmed and interpreted under the Boldt Decision[4] and other subsequent court cases[5] to include the right of Treaty Tribes to harvest up to 50% of all fisheries resources that reside in and/or pass through their U&A. These decisions also establish Treaty Tribes in Washington as legal co-managers of fisheries resources,[6] with similar regulations at the Federal level[7]. Treaty Tribes in the region have sophisticated fisheries management and research capacity. Part of the proposed survey off the Washington coast occurs within the U&A areas of the Hoh Tribe, Makah Tribe, Quileute Tribe, and Quinault Nation. Treaty Tribes' commercial and ceremonial/subsistence fisheries in this region are extensive and include but are not limited to: salmon, halibut, groundfish, flatfish, whiting, and Dungeness crab. Tribes also harvest shellfish such as clams, crab, oysters, and shrimp, and many other species as part of treaty fisheries (NWIFC 2019). Treaty fisheries play an integral role in the economy, nutritional security, and culture of the Treaty Tribes within the study area.

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[4] *United States v. Washington*, 384 F. Supp. 312 (W.D. Wash. 1974), aff'd, 520 F.2d 676, 684-687 (9th Cir. 1975).

[5] *E.g., Washington v. Washington State Commercial Passenger Fishing Vessel Association*, 443 U.S. 658, 685-687 (1979) (salmon); *U.S. v. Washington*, 459 F. Supp. 1020, 1065 (W.D. Wash. 1978) (herring); *U.S. v. Washington*, No. C85-1606R, Subproceeding No. 92-1 (W.D. Wash. Dec. 29, 1993) (halibut); *U.S. v. Washington*, 873 F. Supp. 1422, 1445, n.30 (W.D. Wash. 1994), aff'd in part and rev'd in part, 157 F. 3d 630, 651-652 (9th Cir. 1998) (shellfish); *U.S. v. Washington*, No. 9213, Subproceeding 96-2 (Nov. 4, 1996) (Pacific whiting).

[6] *See generally United States v. Washington*, 384 F. Supp. 312 (W.D. Wash. 1974), aff'd, 520 F.2d 676 (9th Cir. 1975).

[7] *See*, *e.g.*, 50 C.F.R. § 660.50(d)(2).

In Canada, subsistence fishing activity is known as "Food, Social, and Ceremonial (FSC)" harvesting and is practiced by indigenous groups. Salmon are the main species harvested by indigenous communities in FSC fisheries due to their nutritional, cultural, and spiritual significance, but marine mammals, birds, and plants are also taken (Weatherdon et al. 2016). Small quantities of sockeye salmon are principally harvested for subsistence purposes on the west coast Vancouver Island in areas including Clayoquot Sound, Barkley Sound, and Nitinat Inlet (DFO 1999). Halibut as well as herring roe are also harvested (Ainsworth 2015). Under the AAROM (Aboriginal Aquatic resource and Oceans Management) program, DFO supports indigenous groups as they "develop, grow and maintain aquatic resource and oceans management departments" (DFO 2020c). Domestic fishing areas for the Maa-nulth First Nation are located within the proposed study off Vancouver Island. Artisanal fisheries occur for butter clams, lingcod, and abalone; in 2010, subsistence fishing totaled 3690 t, and artisanal landings totaled 2160 t (Ainsworth 2015).

3.8 Aquaculture

In Oregon, the only marine species that is harvested is the Pacific oyster which makes up 44% of the number of farms within the state, valued at $10 million (ODA 2015). There is significant room to diversify and expand the current practices, and to explore possibilities of farming other marine invertebrate species such as the Manila clam, purple varnish clam, mussel, abalone, sea cucumber, and sea urchin (ODA 2015). Classified commercial shellfish growing areas in Oregon include Clatsop beaches, Tillamook Bay, Netarts Bay, Yaquina Bay, Umpqua Triangle, Umpqua River, Coos Bay, and South Slough (ODA 2019).

In 2011, shellfish farming in Washington state contributed $270 million to the economy (Washington Sea Grant 2015). Shellfish aquaculture production regions along the coast include the Strait of Juan de Fuca, Grays Harbor, Willapa Bay, and Puget Sound. The most important farmed species are the Pacific, eastern, and Kumamoto oysters, Olympia oyster, Manila clam, mussels, and geoduck (Washington Sea Grant 2015). The Pacific oyster makes up 38% of the total production of aquaculture in Washington, followed by geoduck (27%) and the Manila clam (19%) (Washington Sea Grant 2015). In 2017, a sea cage site owned by Cooke Aquaculture near Cypress Island, Puget Sound, failed and released 240,000 Atlantic salmon (non-native) into the surrounding waters. Since then, House Bill 2957 was passed by Washington Legislature which stated that all remaining Atlantic salmon pens will be phased out by 2022, and new commercial non-native finfish aquaculture is prohibited (Washington State Department of Ecology 2019).

In 2016, there were 41 licensed marine finfish and 63 licensed shellfish aquaculture facilities on the west coast of Vancouver Island (DFO 2020d). During 2010–2015, finfish aquaculture production generated $454 million (77, 209 t) and shellfish aquaculture generated $21 million (9146 t) for B.C. (VIEA 2017). Most marine finfish aquaculture licenses are issued for Atlantic salmon, chinook, coho, and sockeye salmon, and to a lesser degree, sablefish, steelhead trout, sturgeon, and tilapia (DFO 2017c; VIEA 2019). The majority of finfish aquaculture facilities are located around northern and western Vancouver Island, particularly in Clayoquot Sound. Shellfish aquaculture licenses are issued for Pacific oysters, Manila clams, geoduck, blue and Gallo mussels, and Japanese scallops (BCSGA 2019). On the west coast of Vancouver Island in Barkley Sound several kelp species are farmed and harvested commercially. These species include giant kelp, bull kelp, kombu, and sugar kelp (Canadian Kelp 2019; VIEA 2019).

3.9 Shipwrecks and SCUBA Diving

There are at least 17 shore-accessible SCUBA diving sites along the Oregon coast (ShoreDiving 2019). Wreck dives are popular along the Olympic Peninsula of Washington. Although the Columbia River Bar is nicknamed the *Graveyard of the Pacific* with ~2000 shipwrecks (TheOregonCoast.info 2019), the survey area is located >50 km from the mouth of the Columbia River and would occur in water depths

>60 m, outside the range for recreational SCUBA diving. The West Coast Trail, originally the Dominion Lifesaving Trail, runs for 75 km along the southwest coast of Vancouver Island, and was built to facilitate the rescue of survivors of more than 484 shipwrecks along this stretch of coastline (West Coast Trail Guide 2019). The locations of 25 shipwrecks are included in the West Coast Trail Guide, though there are not visible remains of all 25 wrecks (West Coast Trail Guide 2019). Scuba diving makes up <5% of visitor motivations to travel to Vancouver Island North as tourism is centrally driven by other nature-based activities (Vancouver Island North Tourism Plan 2015). The majority of dive operators (41%) are located on southern Vancouver Island, and 10% are located on northern Vancouver Island and Haida Gwaii (Ivanova 2004). Most diving trips occur during the summer, but diving on the west coast takes place throughout the year (Ivanova 2004). Alberni-Clayoquot is a popular diving area on the west coast of Vancouver Island.

IV ENVIRONMENTAL CONSEQUENCES

4.1 Proposed Action

4.1.1 Direct Effects on Marine Mammals and Sea Turtles and Their Significance

The material in this section includes a summary of the expected potential effects (or lack thereof) of airgun sounds on marine mammals and sea turtles given in the PEIS, and reference to recent literature that has become available since the PEIS was released in 2011. A more comprehensive review of the relevant background information appears in § 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS. Relevant background information on the hearing abilities of marine mammals and sea turtles can also be found in the PEIS.

This section also includes estimates of the numbers of marine mammals that could be affected by the proposed seismic surveys. A description of the rationale for NSF's estimates of the numbers of individuals exposed to received sound levels ≥160 dB re 1 μPa_{rms} is also provided.

4.1.1.1 Summary of Potential Effects of Airgun Sounds

As noted in the PEIS (§ 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3), the effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007; Erbe 2012; Peng et al. 2015; Erbe et al. 2016; Kunc et al. 2016; National Academies of Sciences, Engineering, and Medicine 2017; Weilgart 2017a). In some cases, a behavioral response to a sound can reduce the overall exposure to that sound (e.g., Finneran et al. 2015; Wensveen et al. 2015).

Permanent hearing impairment (PTS), in the unlikely event that it occurred, would constitute injury (Southall et al. 2007; Le Prell 2012). Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if the impulses have very short rise times (e.g., Morell et al. 2017). However, the impulsive nature of sound is range-dependent, becoming less harmful over distance from the source (Hastie et al. 2019). TTS is not considered an injury (Southall et al. 2007; Le Prell 2012). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. Nonetheless, research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Kujawa and Liberman 2009; Liberman et al. 2016). These findings have raised some doubts as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015, 2016). Although the possibility cannot be entirely excluded, it is unlikely that the proposed surveys would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects. If marine mammals encounter a survey while it is underway, some behavioral disturbance could result, but this would be localized and short-term.

***Tolerance*.—**Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers (e.g., Nieukirk et al. 2012). Several studies have shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response. That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen and toothed whales, and (less frequently) pinnipeds have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. The relative responsiveness of baleen and toothed whales are quite variable.

***Masking*.—**Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in exceptional situations, reverberation occurs for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006), which could mask calls. Situations with prolonged strong reverberation are infrequent. However, it is common for reverberation to cause some lesser degree of elevation of the background level between airgun pulses (e.g., Gedamke 2011; Guerra et al. 2011, 2016; Klinck et al. 2012; Guan et al. 2015), and this weaker reverberation presumably reduces the detection range of calls and other natural sounds to some degree. Guerra et al. (2016) reported that ambient noise levels between seismic pulses were elevated as a result of reverberation at ranges of 50 km from the seismic source. Based on measurements in deep water of the Southern Ocean, Gedamke (2011) estimated that the slight elevation of background levels during intervals between pulses reduced blue and fin whale communication space by as much as 36–51% when a seismic survey was operating 450–2800 km away. Based on preliminary modeling, Wittekind et al. (2016) reported that airgun sounds could reduce the communication range of blue and fin whales 2000 km from the seismic source. Kyhn et al. (2019) reported that baleen whales and seals were likely masked over an extended period of time during four concurrent seismic surveys in Baffin Bay, Greenland. Nieukirk et al. (2012), Blackwell et al. (2013), and Dunlop (2018) also noted the potential for masking effects from seismic surveys on large whales,

Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the pulses (e.g., Nieukirk et al. 2012; Thode et al. 2012; Bröker et al. 2013; Sciacca et al. 2016). Cerchio et al. (2014) suggested that the breeding display of humpback whales off Angola could be disrupted by seismic sounds, as singing activity declined with increasing received levels. In addition, some cetaceans are known to change their calling rates, shift their peak frequencies, or otherwise modify their vocal behavior in response to airgun sounds (e.g., Di Iorio and Clark 2010; Castellote et al. 2012; Blackwell et al. 2013, 2015). The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small odontocetes that have been studied directly (e.g., MacGillivray et al. 2014). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses. We are not aware of any information concerning masking of hearing in sea turtles.

***Disturbance Reactions*.—**Disturbance includes a variety of effects, including subtle to conspicuous changes in behavior, movement, and displacement. Based on NMFS (2001, p. 9293), National Research Council (NRC 2005), and Southall et al. (2007), we believe that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, we mean, 'in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations'.

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007; Ellison et al. 2012, 2018). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population (e.g., New et al. 2013a). However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Lusseau and Bejder 2007; Weilgart 2007; New et al. 2013b; Nowacek et al. 2015; Forney et al. 2017). Some studies have attempted modeling to assess consequences of effects from underwater noise at the population level (e.g., King et al. 2015; Costa et al. 2016a,b; Ellison et al. 2016; Harwood et al. 2016; Nowacek et al. 2016; Farmer et al. 2017).

Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many marine mammals would be present within a particular distance of industrial activities and/or exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically important manner. The sound criteria used to estimate how many marine mammals could be disturbed to some biologically important degree by a seismic program are based primarily on behavioral observations of a few species. Detailed studies have been done on humpback, gray, bowhead, and sperm whales. Less detailed data are available for some other species of baleen whales and small toothed whales, but for many species, there are no data on responses to marine seismic surveys.

Baleen Whales

Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the cases of migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors (Malme et al. 1984; Malme and Miles 1985; Richardson et al. 1995).

Responses of *humpback whales* to seismic surveys have been studied during migration, on summer feeding grounds, and on Angolan winter breeding grounds; there has also been discussion of effects on the Brazilian wintering grounds. Off Western Australia, avoidance reactions began at 5–8 km from the array, and those reactions kept most pods ~3–4 km from the operating seismic boat; there was localized displacement during migration of 4–5 km by traveling pods and 7–12 km by more sensitive resting pods of cow-calf pairs (McCauley et al. 1998, 2000). However, some individual humpback whales, especially males, approached within distances of 100–400 m.

Dunlop et al. (2015) reported that migrating humpback whales in Australia responded to a vessel operating a 20 in^3 airgun by decreasing their dive time and speed of southward migration; however, the same responses were obtained during control trials without an active airgun, suggesting that humpbacks responded to the source vessel rather than the airgun. A ramp up was not superior to triggering humpbacks to move away from the vessel compared with a constant source at a higher level of 140 in^3, although an increase in distance from the airgun(s) was noted for both sources (Dunlop et al. 2016a). Avoidance was also shown when no airguns were operational, indicating that the presence of the vessel itself had an effect on the response (Dunlop et al. 2016a,b). Overall, the results showed that humpbacks were more likely to avoid active small airgun sources (20 and 140 in^3) within 3 km and received levels of at least 140 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017a). Responses to ramp up and use of a large 3130 in^3 array elicited greater behavioral changes in humpbacks when compared with small arrays (Dunlop et al. 2016c). Humpbacks deviated from their southbound migration when they were within 4 km of the active large airgun source, where received levels were >130 dB re 1 $\mu Pa^2 \cdot s$ (Dunlop et al. 2017b, 2018). These results are consistent with earlier studies (e.g., McCauley et al. 2000).

In the northwest Atlantic, sighting rates were significantly greater during non-seismic periods compared with periods when a full array was operating, and humpback whales were more likely to swim away and less likely to swim towards a vessel during seismic vs. non-seismic periods (Moulton and Holst 2010). In contrast, sightings of humpback whales from seismic vessels off the U.K. during 1994–2010 indicated that detection rates were similar during seismic and non-seismic periods, although sample sizes were small (Stone 2015). On their summer feeding grounds in southeast Alaska, there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 μPa on an approximate rms basis (Malme et al. 1985). It has been suggested that South Atlantic humpback whales wintering off Brazil may be displaced or even strand upon exposure to seismic surveys (Engel et al. 2004), but data from subsequent years indicated that there was no observable direct correlation between strandings and seismic surveys (IWC 2007).

There are no data on reactions of *right whales* to seismic surveys. However, Rolland et al. (2012) suggested that ship noise causes increased stress in right whales; they showed that baseline levels of stress-related faecal hormone metabolites decreased in North Atlantic right whales with a 6-dB decrease in underwater noise from vessels. Wright et al. (2011), Atkinson et al. (2015), Houser et al. (2016), and Lyamin et al. (2016) also reported that sound could be a potential source of stress for marine mammals.

Bowhead whales show that their responsiveness can be quite variable depending on their activity (migrating vs. feeding). Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source (Miller et al. 1999; Richardson et al. 1999). Subtle but statistically significant changes in surfacing–respiration–dive cycles were shown by traveling and socializing bowheads exposed to airgun sounds in the Beaufort Sea, including shorter surfacings, shorter dives, and decreased number of blows per surfacing (Robertson et al. 2013). More recent research on bowhead whales corroborates earlier evidence that, during the summer feeding season, bowheads are less responsive to seismic sources (e.g., Miller et al. 2005; Robertson et al. 2013).

Bowhead whale calls detected in the presence and absence of airgun sounds have been studied extensively in the Beaufort Sea. Bowheads continue to produce calls of the usual types when exposed to airgun sounds on their summering grounds, although numbers of calls detected are significantly lower in the presence than in the absence of airgun pulses (Blackwell et al. 2013, 2015). Blackwell et al. (2013) reported that calling rates in 2007 declined significantly where received SPLs from airgun sounds were 116–129 dB re 1 μPa; at SPLs <108 dB re 1 μPa, calling rates were not affected. When data for

2007–2010 were analyzed, Blackwell et al. (2015) reported an initial increase in calling rates when airgun pulses became detectable; however, calling rates leveled off at a received $CSEL_{10\text{-min}}$ (cumulative SEL over a 10-min period) of ~94 dB re 1 $\mu Pa^2 \cdot s$, decreased at $CSEL_{10\text{-min}}$ >127 dB re 1 $\mu Pa^2 \cdot s$, and whales were nearly silent at $CSEL_{10\text{-min}}$ >160 dB re 1 $\mu Pa^2 \cdot s$. Thus, bowhead whales in the Beaufort Sea apparently decreased their calling rates in response to seismic operations, although movement out of the area could also have contributed to the lower call detection rate (Blackwell et al. 2013, 2015).

A multivariate analysis of factors affecting the distribution of calling bowhead whales during their fall migration in 2009 noted that the southern edge of the distribution of calling whales was significantly closer to shore with increasing levels of airgun sound from a seismic survey a few hundred kilometers to the east of the study area (i.e., behind the westward-migrating whales; McDonald et al. 2010, 2011). It was not known whether this statistical effect represented a stronger tendency for quieting of the whales farther offshore in deeper water upon exposure to airgun sound, or an actual inshore displacement of whales.

There was no indication that *western gray whales* exposed to seismic sound were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001 (Johnson et al. 2007; Meier et al. 2007; Yazvenko et al. 2007a). However, there were indications of subtle behavioral effects among whales that remained in the areas exposed to airgun sounds (Würsig et al. 1999; Gailey et al. 2007; Weller et al. 2006a) and localized redistribution of some individuals within the nearshore feeding ground so as to avoid close approaches by the seismic vessel (Weller et al. 2002, 2006b; Yazvenko et al. 2007a). Despite the evidence of subtle changes in some quantitative measures of behavior and local redistribution of some individuals, there was no apparent change in the frequency of feeding, as evident from mud plumes visible at the surface (Yazvenko et al. 2007b). Similarly, no large changes in gray whale movement, respiration, or distribution patterns were observed during the seismic programs conducted in 2010 (Bröker et al. 2015; Gailey et al. 2016). Although sighting distances of gray whales from shore increased slightly during a 2-week seismic survey, this result was not significant (Muir et al. 2015). However, there may have been a possible localized avoidance response to high sound levels in the area (Muir et al. 2016). The lack of strong avoidance or other strong responses during the 2001 and 2010 programs was presumably in part a result of the comprehensive combination of real-time monitoring and mitigation measures designed to avoid exposing western gray whales to received SPLs above ~163 dB re 1 μPa_{rms} (Johnson et al. 2007; Nowacek et al. 2012, 2013b). In contrast, preliminary data collected during a seismic program in 2015 showed some displacement of animals from the feeding area and responses to lower sound levels than expected (Gailey et al. 2017; Sychenko et al. 2017).

Gray whales in B.C., Canada, exposed to seismic survey sound levels up to ~170 dB re 1 μPa did not appear to be strongly disturbed (Bain and Williams 2006). The few whales that were observed moved away from the airguns but toward deeper water where sound levels were said to be higher due to propagation effects (Bain and Williams 2006).

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses. Sightings by observers on seismic vessels using large arrays off the U.K. from 1994–2010 showed that the detection rate for minke whales was significantly higher when airguns were not operating; however, during surveys with small arrays, the detection rates for minke whales were similar during seismic and non-seismic periods (Stone 2015). Sighting rates for fin and sei whales were similar when large arrays of airguns were operating vs. silent (Stone 2015). All baleen whales combined tended to exhibit localized avoidance, remaining significantly farther (on average) from large arrays (median closest point of approach or CPA of ~1.5 km) during seismic operations compared with non-seismic periods (median CPA ~1.0 km; Stone 2015). In addition, fin and minke whales were more often oriented away from the vessel while a large airgun array was active compared with periods of inactivity (Stone 2015). Singing fin whales in the Mediterranean moved away from an operating airgun array, and their song notes had lower bandwidths during periods with vs. without airgun sounds (Castellote et al. 2012).

Kavanagh et al. (2019) analyzed more than 8000 hr of cetacean survey data in the northeastern Atlantic Ocean to determine the effects of the seismic surveys on cetaceans. They found that sighting rates of baleen whales were significantly lower during seismic surveys compared with control surveys. During seismic surveys in the northwest Atlantic, baleen whales as a group showed localized avoidance of the operating array (Moulton and Holst 2010). Sighting rates were significantly lower during seismic operations compared with non-seismic periods. Baleen whales were seen on average 200 m farther from the vessel during airgun activities vs. non-seismic periods, and these whales more often swam away from the vessel when seismic operations were underway compared with periods when no airguns were operating (Moulton and Holst 2010). Blue whales were seen significantly farther from the vessel during single airgun operations, ramp up, and all other airgun operations compared with non-seismic periods (Moulton and Holst 2010). Similarly, fin whales were seen at significantly farther distances during ramp up than during periods without airgun operations; there was also a trend for fin whales to be sighted farther from the vessel during other airgun operations, but the difference was not significant (Moulton and Holst 2010). Minke whales were seen significantly farther from the vessel during periods with than without seismic operations (Moulton and Holst 2010). Minke whales were also more likely to swim away and less likely to approach during seismic operations compared to periods when airguns were not operating (Moulton and Holst 2010). However, Matos (2015) reported no change in sighting rates of minke whales in Vestfjorden, Norway, during ongoing seismic surveys outside of the fjord. Vilela et al. (2016) cautioned that environmental conditions should be taken into account when comparing sighting rates during seismic surveys, as spatial modeling showed that differences in sighting rates of rorquals (fin and minke whales) during seismic periods and non-seismic periods during a survey in the Gulf of Cadiz could be explained by environmental variables.

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades. The western Pacific gray whale population continued to feed off Sakhalin Island every summer, despite seismic surveys in the region. In addition, bowhead whales have continued to travel to the eastern Beaufort Sea each summer, and their numbers have increased notably, despite seismic exploration in their summer and autumn range for many years. Pirotta et al. (2018) used a dynamic state model of behavior and physiology to assess the consequences of disturbance (e.g., seismic surveys) on whales (in this case, blue whales). They found that the impact of localized, acute disturbance (e.g., seismic surveys) depended on the whale's behavioral response, with whales that remained in the affected area having a greater risk of reduced reproductive success than whales that avoided the disturbance. Chronic, but weaker disturbance (e.g., vessel traffic) appeared to have less effect on reproductive success.

Toothed Whales

Little systematic information is available about reactions of toothed whales to sound pulses. However, there are recent systematic studies on sperm whales, and there is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies. Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Stone and Tasker 2006; Moulton and Holst 2010; Barry et al. 2012; Wole and Myade 2014; Stone 2015; Monaco et al. 2016). In most cases, the avoidance radii for delphinids appear to be small, on the order of 1 km or less, and some individuals show no apparent avoidance.

Observations from seismic vessels using large arrays off the U.K. from 1994–2010 indicated that detection rates were significantly higher for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins when airguns were not operating; detection rates during seismic vs. non-seismic periods were similar during seismic surveys using small arrays (Stone 2015). Detection rates for long-finned pilot whales, Risso's dolphins, bottlenose dolphins, and short-beaked common dolphins were similar during seismic (small or large array) vs. non-seismic operations (Stone 2015). CPA distances for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins were significantly farther (>0.5 km) from large airgun arrays during periods of airgun activity compared with periods of inactivity, with significantly more animals traveling away from the vessel during airgun operation (Stone 2015). Observers' records suggested that fewer cetaceans were feeding and fewer delphinids were interacting with the survey vessel (e.g., bow-riding) during periods with airguns operating (Stone 2015).

During seismic surveys in the northwest Atlantic, delphinids as a group showed some localized avoidance of the operating array (Moulton and Holst 2010). The mean initial detection distance was significantly farther (by ~200 m) during seismic operations compared with periods when the seismic source was not active; however, there was no significant difference between sighting rates (Moulton and Holst 2010). The same results were evident when only long-finned pilot whales were considered.

Preliminary findings of a monitoring study of *narwhals* in Melville Bay, Greenland, (summer and fall 2012) showed no short-term effects of seismic survey activity on narwhal distribution, abundance, migration timing, and feeding habits (Heide-Jørgensen et al. 2013a). In addition, there were no reported effects on narwhal hunting. These findings do not seemingly support a suggestion by Heide-Jørgensen et al. (2013b) that seismic surveys in Baffin Bay may have delayed the migration timing of narwhals, thereby increasing the risk of narwhals to ice entrapment.

The beluga, however, is a species that (at least at times) shows long-distance (10s of km) avoidance of seismic vessels (e.g., Miller et al. 2005). Captive bottlenose dolphins and beluga whales exhibited changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys, but the animals tolerated high received levels of sound before exhibiting aversive behaviors (e.g., Finneran et al. 2000, 2002, 2005). Schlundt et al. (2016) also reported that bottlenose dolphins exposed to multiple airgun pulses exhibited some anticipatory behavior.

Most studies of *sperm whales* exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses; in most cases the whales do not show strong avoidance (e.g., Stone and Tasker 2006; Moulton and Holst 2010). Winsor et al. (2017) outfitted sperm whales in the Gulf of Mexico with satellite tags to examine their spatial distribution in relation to seismic surveys. They found no evidence of avoidance or changes in orientation by sperm whales to active seismic vessels. Based on data collected by observers on seismic vessels off the U.K. from 1994–2010, detection rates for sperm whales were similar when large arrays of airguns were operating vs. silent; however, during surveys with small arrays, the detection rate was significantly higher when the airguns were not in operation (Stone 2015). Foraging behavior can also be altered upon exposure to airgun sound (e.g., Miller et al. 2009), which according to Farmer et al. (2017), could have significant consequences on individual fitness. Preliminary data from the Gulf of Mexico show a correlation between reduced sperm whale acoustic activity and periods with airgun operations (Sidorovskaia et al. 2014).

There are almost no specific data on the behavioral reactions of *beaked whales* to seismic surveys. Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998) and/or change their behavior in response to sounds from vessels (e.g., Pirotta et al. 2012). Thus, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel. Observations from seismic vessels off the U.K. from 1994–2010 indicated that detection rates of beaked whales were significantly higher (p<0.05) when airguns were not operating vs. when a large array was in operation, although sample sizes were small (Stone 2015). Some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (e.g., Simard et al. 2005).

The limited available data suggest that *harbor porpoises* show stronger avoidance of seismic operations than do Dall's porpoises. The apparent tendency for greater responsiveness in the harbor porpoise is consistent with its relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007). Based on data collected by observers on seismic vessels off the U.K. from 1994–2010, detection rates of harbor porpoises were significantly higher when airguns were silent vs. when large or small arrays were operating (Stone 2015). In addition, harbor porpoises were seen farther away from the array when it was operating vs. silent, and were most often seen traveling away from the airgun array when it was in operation (Stone 2015). Thompson et al. (2013) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 μPa, SELs of 145–151 dB $\mu Pa^2 \cdot s$). For the same survey, Pirotta et al. (2014) reported that the probability of recording a porpoise buzz decreased by 15% in the ensonified area, and that the probability was positively related to the distance from the seismic ship; the decreased buzzing occurrence may indicate reduced foraging efficiency. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013). In a captive facility, harbor porpoise showed avoidance of a pool with elevated sound levels, but search time for prey within that pool was no different than in a quieter pool (Kok et al. 2017).

Kastelein et al. (2013a) reported that a harbor porpoise showed no response to an impulse sound with an SEL below 65 dB, but a 50% brief response rate was noted at an SEL of 92 dB and an SPL of 122 dB re 1 $\mu Pa_{0\text{-peak}}$. However, Kastelein et al. (2012c) reported a 50% detection threshold at a SEL of 60 dB to a similar impulse sound; this difference is likely attributable to the different transducers used during the two studies (Kastelein et al. 2013c). Van Beest et al. (2018) exposed five harbor porpoise to a single 10 in^3 airgun for 1 min at 2–3 s intervals at ranges of 420–690 m and levels of 135–147 dB $\mu Pa^2 \cdot s$. One porpoise moved away from the sound source but returned to natural movement patters within 8 h, and two porpoises had shorter and shallower dives but returned to natural behaviors within 24 h.

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids, seem to be confined to a smaller radius than has been observed for the more responsive of the mysticetes and some other odontocetes. A ≥170 dB disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids, which tend to be less responsive than the more responsive cetaceans. NMFS is developing new guidance for predicting behavioral effects (Scholik-Schlomer 2015). As behavioral responses are not consistently associated with received levels, some authors have made recommendations on different approaches to assess behavioral reactions (e.g., Gomez et al. 2016; Harris et al. 2017; Tyack and Thomas 2019).

Pinnipeds

Pinnipeds are not likely to show a strong avoidance reaction to an airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds and only slight (if any) changes in behavior. However, telemetry work has suggested that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998). Observations from seismic vessels operating large arrays off the U.K. from 1994–2010 showed that the detection rate for gray seals was significantly higher when airguns were not operating; for surveys using small arrays, the detection rates were similar during seismic vs. non-seismic operations (Stone 2015). No significant differences in detection rates were apparent for harbor seals during seismic and non-seismic periods (Stone 2015). There were no significant differences in CPA distances of grey or harbor seals during seismic vs. non-seismic periods (Stone 2015). Lalas and McConnell (2015) made observations of New Zealand fur seals from a seismic vessel operating a 3090 in^3 airgun array in New Zealand during 2009. However, the results from the study were inconclusive in showing whether New Zealand fur seals respond to seismic sounds. Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses; only mild behavioral responses were observed.

Sea Turtles

Several recent papers discuss the morphology of the turtle ear (e.g., Christensen-Dalsgaard et al. 2012; Willis et al. 2013) and the hearing ability of sea turtles (e.g., Martin et al. 2012; Piniak et al. 2012a,b; Lavender et al. 2014). The limited available data indicate that sea turtles will hear airgun sounds and sometimes exhibit localized avoidance (see PEIS, § 3.4.4.3). In additional, Nelms et al. (2016) suggest that sea turtles could be excluded from critical habitats during seismic surveys.

DeRuiter and Doukara (2012) observed that immediately following an airgun pulse, small numbers of basking loggerhead turtles (6 of 86 turtles observed) exhibited an apparent startle response (sudden raising of the head and splashing of flippers, occasionally accompanied by blowing bubbles from the beak and nostrils, followed by a short dive). Diving turtles (49 of 86 individuals) were observed at distances from the center of the airgun array ranging from 50–839 m. The estimated sound level at the median distance of 130 m was 191 dB re 1 μPa_{peak}. These observations were made during ~150 h of vessel-based monitoring from a seismic vessel operating an airgun array (13 airguns, 2440 in^3) off Algeria; there was no corresponding observation effort during periods when the airgun array was inactive (DeRuiter and Doukara 2012).

Based on available data, it is likely that sea turtles will exhibit behavioral changes and/or avoidance within an area of unknown size near a seismic vessel. To the extent that there are any impacts on sea turtles, seismic operations in or near areas where turtles concentrate would likely have the greatest impact. There are no specific data that demonstrate the consequences to sea turtles if seismic operations with large or small arrays of airguns occur in important areas at biologically important times of the year. However, a number of mitigation measures can, on a case-by-case basis, be considered for application in areas important to sea turtles (e.g., Pendoley 1997; van der Wal et al. 2016).

***Hearing Impairment and Other Physical Effects*.—**Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. TTS has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed by Southall et al. 2007; Finneran 2015). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., PTS, in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions.

Additional data are needed to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. To determine how close an airgun array would need to approach in order to elicit TTS, one would (as a minimum) need to allow for the sequence of distances at which airgun pulses would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Breitzke and Bohlen 2010; Laws 2012). At the present state of knowledge, it is also necessary to assume that the effect is directly related to total received energy (SEL); however, this assumption is likely an over-simplification (Finneran 2012). There is recent evidence that auditory effects in a given animal are not a simple function of received acoustic energy (Finneran 2015). Frequency, duration of the exposure, and occurrence of gaps within the exposure can also influence the auditory effect (Finneran and Schlundt 2010, 2011, 2013; Finneran et al. 2010a,b; Popov et al. 2011, 2013; Ketten 2012; Finneran 2012, 2015; Kastelein et al. 2012a,b; 2013b,c, 2014, 2015a, 2016a,b, 2017, 2018, 2019a,b; Supin et al. 2016).

Studies have shown that the SEL required for TTS onset to occur increases with intermittent exposures, with some auditory recovery during silent periods between signals (Finneran et al. 2010b; Finneran and Schlundt 2011). Studies on bottlenose dolphins by Finneran et al. (2015) indicate that the potential for seismic surveys using airguns to cause auditory effects on dolphins could be lower than previously thought. Based on behavioral tests, no measurable TTS was detected in three bottlenose dolphins after exposure to 10 impulses from a seismic airgun with a cumulative SEL of up to ~195 dB re 1 µPa2 · s (Finneran et al. 2015; Schlundt et al. 2016). However, auditory evoked potential measurements were more variable; one dolphin showed a small (9 dB) threshold shift at 8 kHz (Finneran et al. 2015; Schlundt et al. 2016).

Studies have also shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012). When beluga whales were exposed to fatiguing noise with sound levels of 165 dB re 1 µPa for durations of 1–30 min at frequencies of 11.2–90 kHz, the highest TTS with the longest recovery time was produced by the lower frequencies (11.2 and 22.5 kHz); TTS effects also gradually increased with prolonged exposure time (Popov et al. 2013). Additionally, Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015b, 2017) reported that exposure to multiple pulses with most energy at low frequencies can lead to TTS at higher frequencies in some cetaceans, such as the harbor porpoise. When a porpoise was exposed to 10 and 20 consecutive shots (mean shot interval ~17 s) from two airguns with a SEL_{cum} of 188 and 191 $\mu Pa^2 \cdot s$, respectively, significant TTS occurred at a hearing frequency of 4 kHz and not at lower hearing frequencies that were tested, despite the fact that most of the airgun energy was <1 kHz; recovery occurred within 12 min post exposure (Kastelein et al. 2017).

Popov et al. (2016) reported that TTS produced by exposure to a fatiguing noise was larger during the first session (or naïve subject state) with a beluga whale than TTS that resulted from the same sound in subsequent sessions (experienced subject state). Similarly, several other studies have shown that some marine mammals (e.g., bottlenose dolphins, false killer whales) can decrease their hearing sensitivity in order to mitigate the impacts of exposure to loud sounds (e.g., Nachtigall and Supin 2013, 2014, 2015, 2016; Nachtigall et al. 2018).

Previous information on TTS for odontocetes was primarily derived from studies on the bottlenose dolphin and beluga, and that for pinnipeds has mostly been obtained from California sea lions and elephant seals (see § 3.6.4.3, § 3.7.4.3, § 3.8.4.3 and Appendix E of the PEIS). Thus, it is inappropriate to assume that onset of TTS occurs at similar received levels in all cetaceans or pinnipeds (*cf.* Southall et al. 2007). Some cetaceans or pinnipeds could incur TTS at lower sound exposures than are necessary to elicit TTS in the beluga and bottlenose dolphin or California sea lion and elephant seal, respectively.

Several studies on TTS in porpoises (e.g., Lucke et al. 2009; Popov et al. 2011; Kastelein et al. 2012a, 2013a,b, 2014, 2015a) indicate that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes. Kastelein et al. (2012a) exposed a harbor porpoise to octave band noise centered at 4 kHz for extended periods. A 6-dB TTS occurred with SELs of 163 dB and 172 dB for low-intensity sound and medium-intensity sound, respectively; high-intensity sound caused a 9-dB TTS at a SEL of 175 dB (Kastelein et al. 2012a). Kastelein et al. (2013b) exposed a harbor porpoise to a long, continuous 1.5-kHz tone, which induced a 14-dB TTS with a total SEL of 190 dB. Popov et al. (2011) examined the effects of fatiguing noise on the hearing threshold of Yangtze finless porpoises when exposed to frequencies of 32–128 kHz at 140–160 dB re 1 μPa for 1–30 min. They found that an exposure of higher level and shorter duration produced a higher TTS than an exposure of equal SEL but of lower level and longer duration. Popov et al. (2011) reported a TTS of 25 dB for a Yangtze finless porpoise that was exposed to high levels of 3-min pulses of half-octave band noise centered at 45 kHz with an SEL of 163 dB.

For the harbor porpoise, Tougaard et al. (2015) have suggested an exposure limit for TTS as an SEL of 100–110 dB above the pure tone hearing threshold at a specific frequency; they also suggested an exposure limit of $L_{\text{eq-fast}}$ (rms average over the duration of the pulse) of 45 dB above the hearing threshold for behavioral responses (i.e., negative phonotaxis). In addition, according to Wensveen et al. (2014) and Tougaard et al. (2015), M-weighting, as used by Southall et al. (2007), might not be appropriate for the harbor porpoise. Thus, Wensveen et al. (2014) developed six auditory weighting functions for the harbor porpoise that could be useful in predicting TTS onset. Mulsow et al. (2015) suggested that basing weighting functions on equal latency/loudness contours may be more appropriate than M-weighting for marine mammals. Simulation modeling to assess the risk of sound exposure to marine mammals (gray seal and harbor porpoise) showed that SEL is most strongly influenced by the weighting function (Donovan et al. 2017). Houser et al. (2017) provide a review of the development and application of auditory weighting functions, as well as recommendations for future work.

Initial evidence from exposures to non-pulses has also suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do most small odontocetes exposed for similar durations (Kastak et al. 1999, 2005, 2008; Ketten et al. 2001). Kastelein et al. (2012b) exposed two harbor seals to octave-band white noise centered at 4 kHz at three mean received SPLs of 124, 136, and 148 dB re 1 µPa; TTS >2.5 dB was induced at an SEL of 170 dB (136 dB SPL for 60 min), and the maximum TTS of 10 dB occurred after a 120-min exposure to 148 dB re 1 µPa or an SEL of 187 dB. Kastelein et al. (2013c) reported that a harbor seal unintentionally exposed to the same sound source with a mean received SPL of 163 dB re 1 µPa for 1 h induced a 44 dB TTS. For a harbor seal exposed to octave-band white noise centered at 4 kHz for 60 min with mean SPLs of 124–148 re 1 µPa, the onset of PTS would require a level of at least 22 dB above the TTS onset (Kastelein et al. 2013c). Reichmuth et al. (2016) exposed captive spotted and ringed seals to single airgun pulses with SELs of 165–181 dB and SPLs (peak to peak) of 190–207 re 1 µPa; no low-frequency TTS was observed. Harbor seals may be able to decrease their exposure to underwater sound by swimming just below the surface where sound levels are typically lower than at depth (Kastelein et al. 2018).

Hermannsen et al. (2015) reported that there is little risk of hearing damage to harbor seals or harbor porpoises when using single airguns in shallow water. Similarly, it is unlikely that a marine mammal would remain close enough to a large airgun array for sufficiently long to incur TTS, let alone PTS. However, Gedamke et al. (2011), based on preliminary simulation modeling that attempted to allow for various uncertainties in assumptions and variability around population means, suggested that some baleen whales whose CPA to a seismic vessel is 1 km or more could experience TTS.

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that some mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372ff; Gedamke et al. 2011). In terrestrial animals, exposure to sounds sufficiently strong to elicit a large TTS induces physiological and structural changes in the inner ear, and at some high level of sound exposure, these phenomena become non-recoverable (Le Prell 2012). At this level of sound exposure, TTS grades into PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS (e.g., Kastak and Reichmuth 2007; Kastak et al. 2008).

The noise exposure criteria for marine mammals that were released by NMFS (2016a, 2018a) account for the newly-available scientific data on TTS, the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors. For impulsive sounds, such as airgun pulses, the thresholds use dual metrics of cumulative SEL (SEL_{cum} over 24 hours) and Peak SPL_{flat}. Onset of PTS is assumed to be 15 dB higher when considering SEL_{cum} and 6 dB higher when considering SPL_{flat}. Different thresholds are provided for the various hearing groups, including LF cetaceans (e.g., baleen whales), MF cetaceans (e.g., most delphinids), HF cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW).

Nowacek et al. (2013a) concluded that current scientific data indicate that seismic airguns have a low probability of directly harming marine life, except at close range. Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airgun array, and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment. Also, many marine mammals and (to a limited degree) sea turtles show some avoidance of the area where received levels of airgun sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves would reduce or (most likely) avoid any possibility of hearing impairment. Aarts et al. (2016) noted that an understanding of animal movement is necessary in order to estimate the impact of anthropogenic sound on cetaceans.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. Gray and Van Waerebeek (2011) have suggested a cause-effect relationship between a seismic survey off Liberia in 2009 and the erratic movement, postural instability, and akinesia in a pantropical spotted dolphin based on spatially and temporally close association with the airgun array. It is possible that some marine mammal species (i.e., beaked whales) are especially susceptible to injury and/or stranding when exposed to strong transient sounds (e.g., Southall et al. 2007). Ten cases of cetacean strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings (Castellote and Llorens 2016). An analysis of stranding data found that the number of long-finned pilot whale strandings along Ireland's coast increased with seismic surveys operating offshore (McGeady et al. 2016). However, there is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. Morell et al. (2017) examined the inner ears of long-finned pilot whales after a mass stranding in Scotland and reported damage to the cochlea compatible with over-exposure from underwater noise; however, no seismic surveys were occurring in the vicinity in the days leading up to the stranding.

Since 1991, there have been 70 Marine Mammal Unusual Mortality Events (UME) in the U.S. (NOAA 2019j). In a hearing to examine the Bureau of Ocean Energy Management's 2017–2022 OCS Oil and Gas Leasing Program (http://www.energy.senate.gov/public/index.cfm/hearings-and-business-meetings?ID =110E5E8F-3A65-4BEC-9D25-5D843A0284D3), it was Dr. Knapp's (a geologist from the

University of South Carolina) interpretation that there was no evidence to suggest a correlation between UMEs and seismic surveys given the similar percentages of UMEs in the Pacific, Atlantic, and Gulf of Mexico, and the greater activity of oil and gas exploration in the Gulf of Mexico.

Non-auditory effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are especially unlikely to incur non-auditory physical effects. The brief duration of exposure of any given mammal and the planned monitoring and mitigation measures would further reduce the probability of exposure of marine mammals to sounds strong enough to induce non-auditory physical effects.

Sea Turtles

There is substantial overlap in the frequencies that sea turtles detect versus the frequencies in airgun pulses. We are not aware of measurements of the absolute hearing thresholds of any sea turtle to waterborne sounds similar to airgun pulses. In the absence of relevant absolute threshold data, we cannot estimate how far away an airgun array might be audible. Moein et al. (1994) and Lenhardt (2002) reported TTS for loggerhead turtles exposed to many airgun pulses (see § 3.4.4 of the PEIS). This suggests that sounds from an airgun array might cause temporary hearing impairment in sea turtles if they do not avoid the (unknown) radius where TTS occurs (see Nelms et al. 2016). However, exposure duration during the proposed surveys would be much less than during the aforementioned studies. Also, recent monitoring studies show that some sea turtles do show localized movement away from approaching airguns. At short distances from the source, received sound level diminishes rapidly with increasing distance. In that situation, even a small-scale avoidance response could result in a significant reduction in sound exposure.

The U.S. Navy has proposed the following criteria for the onset of hearing impairment for sea turtles: 232 dB re 1 µPa SPL (peak) and 204 dB re 1 $\mu Pa^2 \cdot s$ SEL_{cum} (weighted) for PTS; and 226 dB peak and 189 dB weighted SEL for TTS (USN 2017). Although it is possible that exposure to airgun sounds could cause mortality or mortal injuries in sea turtles close to the source, this has not been demonstrated and seems highly unlikely (Popper et al. 2014), especially because sea turtles appear to be resistant to explosives (Ketten et al. 2005 *in* Popper et al. 2014). Nonetheless, Popper et al. (2014) proposed sea turtle mortality/mortal injury criteria of 210 dB SEL or >207 dB_{peak} for sounds from seismic airguns; however, these criteria were largely based on impacts of pile-driving sound on fish.

The PSOs stationed on R/V *Langseth* would watch for sea turtles, and airgun operations would be shut down if a turtle enters the designated EZ.

4.1.1.2 Possible Effects of Other Acoustic Sources

The Kongsberg EM 122 MBES and Knudsen Chirp 3260 SBP would be operated from the source vessel during the proposed surveys. Information about this equipment was provided in § 2.2.3.1 of the PEIS. A review of the expected potential effects (or lack thereof) of MBESs, SBPs, and pingers on marine mammals and sea turtles appears in § 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.

There has been some recent attention given to the effects of MBES on marine mammals, as a result of a report issued in September 2013 by an IWC independent scientific review panel linking the operation of an MBES to a mass stranding of melon-headed whales off Madagascar (Southall et al. 2013). During May–June 2008, ~100 melon-headed whales entered and stranded in the Loza Lagoon system in northwest Madagascar at the same time that a 12-kHz MBES survey was being conducted ~65 km away off the coast. In conducting a retrospective review of available information on the event, an independent scientific review panel concluded that the Kongsberg EM 120 MBES was the most plausible behavioral trigger for the animals initially entering the lagoon system and eventually stranding. The independent scientific review panel, however, identified that an unequivocal conclusion on causality of the event was not possible because of the lack of information about the event and a number of potentially contributing factors. Additionally, the independent review panel report indicated that this incident was likely the result of a complicated confluence of environmental, social, and other factors that have a very low probability of occurring again in the future, but recommended that the potential be considered in environmental planning. It should be noted that this event is the first known marine mammal mass stranding closely associated with the operation of an MBES. Leading scientific experts knowledgeable about MBES expressed concerns about the independent scientific review panel analyses and findings (Bernstein 2013).

Reference has also been made that two beaked whales stranded in the Gulf of California in 2002 were observed during a seismic survey in the region by the R/V *Ewing* (Malakoff 2002, Cox et al. 2006 *in* PEIS:3-136), which used a similar MBES system. As noted in the PEIS, however, "The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence" (Hogarth 2002, Yoder 2002 *in* PEIS:3-190).

Lurton (2016) modeled MBES radiation characteristics (pulse design, source level, and radiation directivity pattern) applied to a low-frequency (12-kHz), 240-dB source-level system like that used on R/V *Langseth*. Using Southall et al. (2007) thresholds, he found that injury impacts were possible only at very short distances, e.g., at 5 m for maximum SPL and 12 m for cumulative SEL for cetaceans; corresponding distances for behavioral response were 9 m and 70 m. For pinnipeds, "all ranges are multiplied by a factor of 4" (Lurton 2016:209).

There is nearly no available information on marine mammal behavioral responses to MBES sounds (Southall et al. 2013) or sea turtle responses to MBES systems. Much of the literature on marine mammal response to sonars relates to the types of sonars used in naval operations, including low-frequency, mid-frequency, and high-frequency active sonars (see review by Southall et al. 2016). However, the MBES sounds are quite different from naval sonars. Ping duration of the MBES is very short relative to naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; naval sonars often use near-horizontally-directed sound. In addition, naval sonars have higher duty cycles. These factors would all reduce the sound energy received from the MBES relative to that from naval sonars.

During a recent study, group vocal periods (GVP) were used as proxies to assess foraging behavior of Cuvier's beaked whales during multibeam mapping in southern California (Varghese et al. 2019). The study found that there was no significant difference between GVP during multibeam mapping and non-exposure periods, but the number of GVP was significantly greater after MBES exposure than before MBES exposure. During an analogous study assessing Naval sonar (McCarthy et al. 2011), significantly fewer GVPs were recorded during sonar transmission (McCarthy et al. 2011; Varghese et al. 2019).

In the fall of 2006, an Ocean Acoustic Waveguide Remote Sensing (OAWRS) experiment was carried out in the Gulf of Maine (Gong et al. 2014); the OAWRS emitted three frequency-modulated (FM) pulses centered at frequencies of 415, 734, and 949 Hz (Risch et al. 2012). Risch et al. (2012) found a reduction in humpback whale song in the Stellwagen Bank National Marine Sanctuary during OAWRS activities that were carried out ~200 km away; received levels in the sanctuary were 88–110 dB re 1 µPa. In contrast, Gong et al. (2014) reported no effect of the OAWRS signals on humpback whale vocalizations in the Gulf of Maine. Range to the source, ambient noise, and/or behavioral state may have differentially influenced the behavioral responses of humpbacks in the two areas (Risch et al. 2014).

Deng et al. (2014) measured the spectral properties of pulses transmitted by three 200-kHz echosounders and found that they generated weaker sounds at frequencies below the center frequency (90–130 kHz). These sounds are within the hearing range of some marine mammals, and the authors suggested that they could be strong enough to elicit behavioral responses within close proximity to the sources, although they would be well below potentially harmful levels. Hastie et al. (2014) reported behavioral responses by gray seals to echosounders with frequencies of 200 and 375 kHz. Short-finned pilot whales increased their heading variance in response to an EK60 echosounder with a resonant frequency of 38 kHz (Quick et al. 2017), and significantly fewer beaked whale vocalizations were detected while an EK60 echosounder was active vs. passive (Cholewiak et al. 2017).

Despite the aforementioned information that has recently become available, this Final EA remains in agreement with the assessment presented in § 3.4.7, 3.6.7, 3.7.7, and 3.8.7 of the PEIS that operation of MBESs, SBPs, and pingers is not likely to impact marine mammals and is not expected to affect sea turtles, (1) given the lower acoustic exposures relative to airguns and (2) because the intermittent and/or narrow downward-directed nature of these sounds would result in no more than one or two brief ping exposures of any individual marine mammal or sea turtle given the movement and speed of the vessel. Also, for sea turtles, the associated frequency ranges are above their known hearing range.

4.1.1.3 Other Possible Effects of Seismic Surveys

Other possible effects of seismic surveys on marine mammals and/or sea turtles include masking by vessel noise, disturbance by vessel presence or noise, and injury or mortality from collisions with vessels or entanglement in seismic gear.

Vessel noise from R/V *Langseth* could affect marine animals in the proposed survey area. Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels, and Putland et al. (2018) also reported reduced sound levels with decreased vessel speed. Sounds produced by large vessels generally dominate ambient noise at frequencies from 20–300 Hz (Richardson et al. 1995). However, some energy is also produced at higher frequencies (Hermannsen et al. 2014); low levels of high-frequency sound from vessels have been shown to elicit responses in harbor porpoise (Dyndo et al. 2015). Increased levels of ship noise also affect foraging by porpoise (Teilmann et al. 2015; Wisniewska et al. 2018). Wisniewska et al. (2018) suggest that a decrease in foraging success could have long-term fitness consequences.

Ship noise, through masking, can reduce the effective communication distance of a marine mammal if the frequency of the sound source is close to that used by the animal, and if the sound is present for a significant fraction of time (e.g., Richardson et al. 1995; Clark et al. 2009; Jensen et al. 2009; Gervaise et al. 2012; Hatch et al. 2012; Rice et al. 2014; Dunlop 2015; Erbe et al. 2016; Jones et al. 2017; Putland et al. 2017; Cholewiak et al. 2018). In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter et al. 2013, 2016; Finneran and Branstetter 2013; Sills et al. 2017). Branstetter et al. (2013) reported that time-domain metrics are also important in describing and predicting masking. In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from shipping, shift their peak frequencies, or otherwise change their vocal behavior (e.g., Parks et al. 2011, 2012, 2016a,b; Castellote et al. 2012; Melcón et al. 2012; Azzara et al. 2013; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Papale et al. 2015; Bittencourt et al. 2016; Dahlheim and Castellote 2016; Gospić and Picciulin 2016; Gridley et al. 2016; Heiler et al. 2016; Martins et al. 2016; O'Brien et al. 2016; Tenessen and Parks 2016; Fornet et al. 2018). Similarly, harbor seals increased the minimum frequency and amplitude of their calls in response to vessel noise (Matthews

2017); however, harp seals did not increase their call frequencies in environments with increased low-frequency sounds (Terhune and Bosker 2016).

Holt et al. (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals. A negative correlation between the presence of some cetacean species and the number of vessels in an area has been demonstrated by several studies (e.g., Campana et al. 2015; Culloch et al. 2016; Oakley et al. 2017). Based on modeling, Halliday et al. (2017) suggested that shipping noise can be audible more than 100 km away and could affect the behavior of a marine mammal at a distance of 52 km in the case of tankers.

Baleen whales are thought to be more sensitive to sound at these low frequencies than are toothed whales (e.g., MacGillivray et al. 2014), possibly causing localized avoidance of the proposed survey areas during seismic operations. Reactions of gray and humpback whales to vessels have been studied, and there is limited information available about the reactions of right whales and rorquals (fin, blue, and minke whales). Reactions of humpback whales to boats are variable, ranging from approach to avoidance (Payne 1978; Salden 1993). Baker et al. (1982, 1983) and Baker and Herman (1989) found humpbacks often move away when vessels are within several kilometers. Humpbacks seem less likely to react overtly when actively feeding than when resting or engaged in other activities (Krieger and Wing 1984, 1986). Increased levels of ship noise have been shown to affect foraging by humpback whales (Blair et al. 2016), and physical presence of vessels, not just ship noise, has been shown to disturb the foraging activity of blue whales (Lesage et al. 2017). Fin whale sightings in the western Mediterranean were negatively correlated with the number of vessels in the area (Campana et al. 2015). Minke whales and gray seals have shown slight displacement in response to construction-related vessel traffic (Anderwald et al. 2013).

Many odontocetes show considerable tolerance of vessel traffic, although they sometimes react at long distances if confined by ice or shallow water, if previously harassed by vessels, or have had little or no recent exposure to ships (Richardson et al. 1995). Dolphins of many species tolerate and sometimes approach vessels (e.g., Anderwald et al. 2013). Some dolphin species approach moving vessels to ride the bow or stern waves (Williams et al. 1992). Physical presence of vessels, not just ship noise, has been shown to disturb the foraging activity of bottlenose dolphins (Pirotta et al. 2015). Sightings of striped dolphin, Risso's dolphin, sperm whale, and Cuvier's beaked whale in the western Mediterranean were negatively correlated with the number of vessels in the area (Campana et al. 2015). Killer whales rarely show avoidance to boats within 400 m (Duffus and Dearden 1993), but when more than one boat is nearby, they sometimes swim faster towards less confined waters (e.g., Williams et al. 2002a,b). Killer whales have also been shown to increase travelling and decrease foraging behavior because of the presence of nearby vessels (Williams et al. 2002a,b, 2009; Lusseau et al. 2009; Noren et al. 2009; Holt et al. 2021).

There are few data on the behavioral reactions of beaked whales to vessel noise, though they seem to avoid approaching vessels (e.g., Würsig et al. 1998) or dive for an extended period when approached by a vessel (e.g., Kasuya 1986). Based on a single observation, Aguilar Soto et al. (2006) suggest foraging efficiency of Cuvier's beaked whales may be reduced by close approach of vessels. Tyson et al. (2017) suggested that a juvenile green sea turtle dove during vessel passes and remained still near the sea floor.

The PEIS concluded that project vessel sounds would not be at levels expected to cause anything more than possible localized and temporary behavioral changes in marine mammals or sea turtles, and would not be expected to result in significant negative effects on individuals or at the population level. In addition, in all oceans of the world, large vessel traffic is currently so prevalent that it is commonly considered a usual source of ambient sound.

Another concern with vessel traffic is the potential for striking marine mammals or sea turtles (e.g., Redfern et al. 2013). Information on vessel strikes is reviewed in § 3.4.4.4, § 3.6.4.4, and § 3.8.4.4 of the PEIS. Reducing ship speed drastically reduced the overall risk of ship strikes (Wiley et al. 2016; Leaper et al. 2019). Similarly, Currie et al. (2017) found a significant decrease in close encounters with humpback whales in the Hawaiian Islands, and therefore reduced likelihood of ship strike, when vessels speeds were below 12.5 kt. However, McKenna et al. (2015) noted the potential absence of lateral avoidance demonstrated by blue whales and perhaps other large whale species to vessels. The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals or sea turtles exists but is extremely unlikely, because of the relatively slow operating speed (typically 7–9 km/h) of the vessel during seismic operations, and the generally straight-line movement of the seismic vessel. There has been no history of marine mammal vessel strikes with R/V *Langseth*, or its predecessor, R/V *Maurice Ewing* over the last two decades.

Entanglement of sea turtles in seismic gear is also a concern (Nelms et al. 2016). There have been reports of turtles being trapped and killed between the gaps in tail-buoys offshore from West Africa (Weir 2007); however, these tailbuoys are significantly different than those used on R/V *Langseth*. In April 2011, a dead olive ridley turtle was found in a deflector foil of the seismic gear on R/V *Langseth* during equipment recovery at the conclusion of a survey off Costa Rica, where sea turtles were numerous. Such incidents are possible, but that was the only case of sea turtle entanglement in seismic gear for R/V *Langseth*, which has been conducting seismic surveys since 2008, or for its predecessor, R/V *Maurice Ewing*, during 2003–2007. Towing the seismic equipment during the proposed surveys is not expected to significantly interfere with sea turtle movements, including migration.

4.1.1.4 Mitigation Measures

Several mitigation measures are built into the proposed seismic surveys as an integral part of the planned activity. These measures include the following: ramp ups; typically two, however a minimum of one dedicated observer maintaining a visual watch during all daytime airgun operations; two observers for 30 min before and during ramp ups in U.S. waters and for 60 min before and during ramp ups in Canadian waters; PAM during the day and night to complement visual monitoring (unless the system is temporarily damaged during operations); shut downs when marine mammals are detected in or about to enter designated EZ; and power downs (or if necessary shut downs) when sea turtles or listed seabird species are detected in or about to enter the EZ. These mitigation measures are described in § 2.4.4.1 of the PEIS and summarized earlier in this document, in § II (2.1.3), along with the special mitigation measures required. The fact that the airgun array, because of its design, would direct the majority of the energy downward, and less energy laterally, is also an inherent mitigation measure.

Previous and subsequent analysis of the potential impacts takes account of these planned mitigation measures. It would not be meaningful to analyze the effects of the planned activity without mitigation, as the mitigation (and associated monitoring) measures are a basic part of the activity and would be implemented under the Proposed Action.

4.1.1.5 Potential Numbers of Marine Mammals Exposed to Received Sound Levels ≥160 dB

All takes would be anticipated to be Level B "takes by harassment" as described in § I, involving temporary changes in behavior. Consistent with past similar proposed actions, NSF has followed the NOAA *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes. Although NMFS may issue Level A takes for the remote possibility of low-level physiological effects, because of the characteristics of the proposed activities and the proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, injurious takes would not be expected. (However, as noted earlier and in the PEIS, there is no specific information demonstrating that injurious Level A "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to Level A and Level B sound levels and present estimates of the numbers of marine mammals that could be affected during the proposed seismic surveys. The estimates are based on consideration of the number of marine mammals that could be harassed by sound (Level B takes) produced by the seismic surveys but exclude potential takes in Canadian Territorial Waters.

The Level B estimates are based on a consideration of the number of marine mammals that could be within the area around the operating airgun array where received levels of sound ≥160 dB re 1 μPa_{rms} are predicted to occur (see Table 1). The estimated numbers are based on the densities (numbers per unit area) of marine mammals expected to occur in the survey area in the absence of a seismic survey. To the extent that marine mammals tend to move away from seismic sources before the sound level reaches the criterion level and tend not to approach an operating airgun array, these estimates likely overestimate the numbers actually exposed to the specified level of sound. The overestimation is expected to be particularly large when dealing with the higher sound level criteria, i.e., the PTS thresholds (Level A), as animals are more likely to move away when received levels are higher. Thus, they are less likely to approach within the PTS threshold radii than they are to approach within the considerably larger ≥160 dB (Level B) radius.

Extensive systematic aircraft- and ship-based surveys have been conducted for marine mammals in offshore waters of Oregon and Washington (e.g., Bonnell et al. 1992; Green et al. 1992, 1993; Barlow 1997, 2003; Barlow and Taylor 2001; Calambokidis and Barlow 2004; Barlow and Forney 2007; Forney 2007; Barlow 2010). Ship surveys for cetaceans in slope and offshore waters of Oregon and Washington were conducted by NMFS/SWFSC in 1991, 1993, 1996, 2001, 2005, 2008, and 2014 and synthesized by Barlow (2016); these surveys were conducted up to ~556 km from shore from June or August to November or December. These data were used by SWFSC to develop spatial models of cetacean densities for the CCE. Systematic, offshore, at-sea survey data for pinnipeds are more limited; the most comprehensive studies are reported by Bonnell et al. (1992) based on systematic aerial surveys conducted in 1989–1990. In B.C., several systematic surveys have been conducted in coastal waters (e.g., Williams and Thomas 2007; Ford et al. 2010a; Best et al. 2015; Harvey et al. 2017). Surveys in coastal as well as offshore waters were conducted by DFO during 2002 to 2008; however, little effort occurred off the west coast of Vancouver Island during late spring/summer (Ford et al. 2010a).

The U.S. Navy primarily used SWFSC spatial models to develop a marine species density database for the Northwest Training and Testing Study Area (USN 2019a), which encompasses the U.S. portion of the proposed survey area; if no density spatial modeling was available, other data sources were used (USN 2019a). The USN marine species density database is at this time the most comprehensive density data set available for the CCE. However, GIS data layers are currently unavailable for the database; thus, in this analysis the USN data were used only for species for which density data were not available from an alternative spatially-explicit model (e.g., minke, sei, gray, false killer, killer, and short-finned pilot whales, *Kogia* spp., and pinnipeds). As recommended by NMFS, spatially-explicit density data from the NOAA CetSound website (NOAA 2019k) were used for most other species (i.e., humpback, blue, fin, sperm, Baird's beaked, and other small beaked whales; bottlenose, striped, short-beaked common, Pacific white-sided, Risso's, and northern right whale dolphins; and Dall's porpoise). CetMap (https://cetsound.noaa.gov/cda) provides output from habitat-based density models for cetaceans in the CCE. As CetMap provides output from habitat-based density models for cetaceans in the CCE (Becker et al. 2016) in the form of GIS layers; these were used to calculate takes in the survey area. As CetMap did not have a spatially-explicit GIS density layer for the harbor porpoise, densities from Forney et al. (2014) were used for that species. Densities used in the analysis are shown in Table B-1 of Appendix B.

Oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the North Pacific Ocean, resulting in considerable year-to-year variation in the distribution and abundance of many marine mammal species (Forney and Barlow 1998; Buchanan et al. 2001; Ferrero et al. 2002; Philbrick et al. 2003; Escorza-Treviño 2009). Thus, for some species, the densities derived from past surveys may not be representative of the densities that would be encountered during the proposed seismic surveys. However, the approach used here is based on the best available data.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 μPa_{rms} criterion for all marine mammals. It is assumed that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered "taken by harassment". Table 8 shows the estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the proposed seismic surveys if no animals moved away from the survey vessel (see Appendix B for more details). These are based on revised seismic transects (as shown in Fig. 1) and changes made to the mitigation radii after the Draft EA was released. When seasonal densities were available, the calculated exposures were based on late spring/summer densities, which were deemed to be most representative of the proposed survey timing. It should be noted that the exposure estimates assume that the proposed surveys would be completed in their entirety. Thus, the following estimates of the numbers of marine mammals potentially exposed to sounds ≥160 dB re 1 μPa_{rms} are precautionary and probably overestimate the actual numbers of marine mammals that could be involved.

Consideration should be given to the hypothesis that delphinids are less responsive to airgun sounds than are mysticetes, as referenced in the NSF/USGS PEIS. The 160-dB_{rms} criterion currently applied by NMFS, on which the Level B estimates are based, was developed primarily using data from gray and bowhead whales. The estimates of "takes by harassment" of delphinids are thus considered precautionary. Available data suggest that the current use of a 160-dB criterion could be improved upon, as behavioral response might not occur for some percentage of marine mammals exposed to received levels >160 dB, whereas other individuals or groups might respond in a manner considered as "taken" to sound levels <160 dB (NMFS 2013b). It has become evident that the context of an exposure of a marine mammal to sound can affect the animal's initial response to the sound (NMFS 2013b).

The number of marine mammals that could be exposed to airgun sounds with received levels ≥160 dB re 1 μPa_{rms} (Level B) for marine mammals on one or more occasions have been calculating based on the marine area that would be within the Level B threshold around the operating seismic source, along with the expected density of animals in the area. The area expected to be ensonified was determined by entering the planned survey lines into a MapInfo GIS, using GIS to identify the relevant areas by "drawing" the applicable 160-dB (Table 1) and PTS threshold buffers (Table 2) around each line (see Appendix B). The approach assumes that no marine mammals would move away or toward the trackline in response to increasing sound levels before the levels reach the specific thresholds as R/V *Langseth* approaches.

After elimination of several transect lines in shallow water, NSF expects no takes of sea otters as no regularly-used sea otter habitat would be expected to be ensonified during the proposed survey. However, USFWS estimated that there could be 13 sea otter takes during the proposed surveys (see Appendix D). As all sea otter habitat in B.C. that was estimated to be ensonified occurred within Canadian Territorial Waters, no takes were calculated for B.C.

TABLE 8. Estimates of the possible numbers of individual marine mammals and sea turtles that could be exposed to Level B and Level A thresholds for various hearing groups during the proposed seismic surveys in the Northeast Pacific Ocean during late spring/summer 2021. Takes for Canadian Territorial Waters are not included here. Species in italics are listed under the ESA as *endangered* or *threatened*.

Species	Calculated Take Level B[1]	Calculated Take Level A[2]	Regional Population Size	Level B + Level A as % of Pop.[3]	Requested Take Authorization[4]
LF Cetaceans					
North Pacific right whale	*0*	*0*	*400*	*0*	*0*
Humpback whale[5]	*111*	*28*	*10,103*	*1.4*	*139*
Blue whale	*40*	*11*	*1,496*	*3.4*	*51*
Fin whale	*94*	*1*	*18,680*	*0.5*	*95*
Sei whale	*30*	*2*	*27,197*	*0.1*	*32*
Minke whale	96	7	20,000	0.5	103
Gray whale	43	1	26,960	0.2	44
MF Cetaceans					
Sperm whale	*72*	*0*	*26,300*	*0.3*	*72*
Baird's beaked whale	84	0	2,697	3.1	84
Small beaked whale[6]	242	0	6,318	3.8	242
Bottlenose dolphin[7]	1	0	1,924	0	**13**
Striped dolphin[7]	7	0	29,211	0	**46**
Short-beaked common dolphin[7]	112	0	969,861	0	**179**
Pacific white-sided dolphin	6,084	9	48,974	12.4	6,093
Northern right-whale dolphin	4,318	2	26,556	16.3	4,320
Risso's dolphin	1,664	5	6,336	26.3	1,669
False killer whale[8]	N.A.	N.A.	N.A.	N.A.	**5**
Killer whale[9]	73	0	918	8.0	73
Short-finned pilot whale[7]	20	0	836	2.4	**29**
HF Cetaceans					
Pygmy/dwarf sperm whale	125	5	4,111	3.2	130
Dall's porpoise	9,762	488	31,053	33.0	10,250
Harbor porpoise	7,958	283	53,773	15.3	8,241
Otariid Seals					
Northern fur seal	4,416	8	620,660	0.7	4,424
Guadalupe fur seal[10]	2,033	15	34,187	6.0	*2,048*
California sea lion	888	1	257,606	0.3	889
Steller sea lion	7,255	249	77,149	9.7	7,504
Phocid Seal					
Northern elephant seal	2,735	19	179,000	1.5	2,754
Harbor seal	3,865	22	129,732	3.0	3,887
Fissiped					
Northern Sea Otter[11]	N.A.	N.A.	2,928	0.4	13
Sea Turtle					
Leatherback turtle	*3*	*0*	*N.A.*	*N.A.*	*3*

N.A. means not applicable or not available. [1]Level B takes, based on the 160-dB criterion, excluding exposures to sound levels equivalent to PTS thresholds. [2]Level A takes if there were no mitigation measures. [3]Requested take authorization is Level A plus Level B calculated takes, used by NMFS as proxy for number of individuals exposed. [4]Requested take authorization (Level A + Level B) expressed as % of population off California/Oregon/Washington, Eastern North Pacific, or U.S. stock (see Table 5). [5]All takes are assumed to be from the ESA-listed Central America and Mexico DPSs. [6] Requested take includes 7 Blainville's, 84 Stejneger's, 84 Cuvier's, and 67 Hubbs' beaked whales (see Appendix B). [7]Requested take increased to mean group size (Barlow 2016). [8]Requested take increased to mean group size (Mobley et al. 2000). [9]Includes individuals from all stocks; NMFS calculated that there would be 10 takes of killer whales from the southern resident stock (see Appendix C). [10]This is an overestimate, as Guadalupe fur seals are not expected to occur in Canadian waters. [11]Takes calculated by USFWS (see Appendix D).

Estimates of the numbers of marine mammals and sea turtles that could be exposed to seismic sounds with received levels equal to Level A thresholds for various hearing groups (see Table 2), if there were no mitigation measures (shut downs when PSOs detected animals approaching or inside the EZs), are also given in Table 8. Those numbers likely overestimate actual Level A takes because the predicted Level A EZs are small and mitigation measures would further reduce the chances of, if not eliminate, any such takes. In addition, most marine mammals would move away from a sound source before they are exposed to sound levels that could result in a Level A take. Dall's porpoise could be more susceptible to exposure to sound levels that exceed the PTS threshold than other marine mammals, as it is known to approach vessels to bowride. However, Level A takes are considered highly unlikely for most marine mammal species that could be encountered in the proposed survey area.

Although the % of the population estimated to be ensonified during the surveys are large for Risso's dolphin (26.3%) and Dall's porpoise (~33.0%), these are likely overestimates. As noted above, densities derived from past surveys may not be representative of the densities that would be encountered during the proposed seismic surveys because of considerable year-to-year variability in oceanographic conditions. If densities from Barlow (2016) are used, the calculations result in takes of 14.8% of the population for Risso's dolphin, and 17.1% of the Dall's porpoise population; depending on the oceanographic conditions during the survey, these estimates may be more representative. In addition, the individuals are wide-ranging, and it is likely that some individuals would be ensonified multiple times instead of many different individuals being exposed during the survey. Also, only two sightings of 10 Risso's dolphins were seen during the L-DEO surveys off Washington/Oregon late spring/summer 2012 (RPS 2012a,b,c).

4.1.1.6 Conclusions for Marine Mammals and Sea Turtles

The proposed seismic surveys would involve towing a 36-airgun array, which introduces pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking".

Marine Mammals.—In § 3.6.7, § 3.7.7, § 3.8.7, and § 3.9.7 of the PEIS concluded that airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some mysticete, odontocete, and pinniped species, as well as sea otters, and that Level A effects were highly unlikely. Consistent with past similar proposed actions, NSF has followed the *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* for estimating Level A takes for the Proposed Action, however, following a different methodology than used in the PEIS and most previous analyses for NSF-funded seismic surveys. For recently NSF-funded seismic surveys, NMFS issued small numbers of Level A take for some marine mammal species for the remote possibility of low-level physiological effects; however, NMFS expected neither mortality nor serious injury of marine mammals to result from the surveys (e.g., NMFS 2019b,c).

In this analysis, estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested "take authorization". The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level A and/or B harassment are low percentages of the regional population sizes (Table 8). The proposed activities are likely to adversely affect ESA-listed species for which takes are being requested (Table 9). However, the relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations.

TABLE 9. ESA determination for marine mammal species expected to be encountered during the proposed surveys in the Northeast Pacific Ocean during late spring/summer 2021.

Species	ESA Determination		
	No Effect	May Affect – Not Likely to Adversely Affect	May Affect – Likely to Adversely Affect
North Pacific Right Whale		√	
Humpback Whale (Central America DPS)			√
Humpback Whale (Mexico DPS)			√
Sei Whale			√
Fin Whale			√
Blue Whale			√
Gray Whale (Western North Pacific Population)	√		
Sperm Whale			√
Killer Whale (Southern Resident DPS)			√
Steller Sea Lion (Western DPS)	√		
Guadalupe Fur Seal			√

In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, R/V *Ewing*, PSOs and other crew members have seen no seismic sound-related marine mammal injuries or mortality. A similar survey conducted in the region in the past (Marine Geophysical Surveys by R/V *Marcus G. Langseth* in the Northeastern Pacific Ocean, June–July 2012) had no observed significant impacts. Also, Also, actual numbers of animals potentially exposed to sound levels sufficient to cause disturbance (i.e., are considered takes) have almost always been much lower than predicted and authorized takes. For example, during an NSF-funded, ~5000-km, 2-D seismic survey conducted by R/V *Langseth* off the coast of North Carolina in September–October 2014, only 296 cetaceans were observed within the predicted 160-dB zone and potentially taken, representing <2% of the 15,498 takes authorized by NMFS (RPS 2015). During an USGS-funded, ~2700 km, 2-D seismic survey conducted by R/V *Langseth* along the U.S. east coast in August–September 2014, only 3 unidentified dolphins were observed within the predicted 160-dB zone and potentially taken, representing <0.03% of the 11,367 authorized takes (RPS 2014b). Furthermore, as defined, all animals exposed to sound levels >160 dB are Level B 'takes' whether or not a behavioral response occurred. The Level B estimates are thought to be conservative; thus, not all animals detected within this threshold distance would be expected to have been exposed to actual sound levels >160 dB.

***Sea Turtles*.—**In § 3.4.7, the PEIS concluded that with implementation of the proposed monitoring and mitigation measures, no significant impacts of airgun operations are likely to sea turtle populations in any of the analysis areas, and that any effects are likely to be limited to short-term behavioral disturbance and short-term localized avoidance of an area of unknown size near the active airguns. In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, R/V *Ewing*, PSOs and other crew members have seen no seismic sound-related sea turtle injuries or mortality. Given the proposed activities, impacts would not be anticipated to be significant or likely to adversely affect green turtles, but they would likely adversely affect the leatherback sea turtle (Table 10).

4.1.2 Direct Effects on Marine Invertebrates, Fish, and Fisheries, and Their Significance

Effects of seismic sound on marine invertebrates (crustaceans and cephalopods), marine fish, and their fisheries are discussed in § 3.2.4 and § 3.3.4 and Appendix D of the PEIS. Relevant new studies on the effects of sound on marine invertebrates, fish, and fisheries that have been published since the release of the PEIS are summarized below. Although research on the effects of exposure to airgun sound on marine invertebrates and fishes is increasing, many data gaps remain (Hawkins et al. 2015; Carroll et al. 2017), including how particle motion rather than sound pressure levels affect invertebrates and fishes that are exposed to sound (Hawkins and Popper 2017; Popper and Hawkins 2018). It is important to note that while

TABLE 10. ESA determination for sea turtle species expected to be encountered during the proposed surveys in the Northeast Pacific Ocean during late spring/summer 2021.

Species	ESA Determination		
	No Effect	May Affect – Not Likely to Adversely Affect	May Affect – Likely to Adversely Affect
Leatherback Turtle			√
Green Turtle (East Pacific DPS)		√	

all invertebrates and fishes are likely sensitive to particle motion, no invertebrates and not all fishes (e.g., sharks) are sensitive to the sound pressure component.

4.1.2 Direct Effects on Marine Invertebrates, Fish, and Fisheries, and Their Significance

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Substrate vibrations caused by sounds may also affect the epibenthos, but sensitivities are largely unknown (Roberts and Elliott 2017). Nonetheless, several studies have found that substrate-borne vibration and sound elicit behavioral responses in crabs (e.g., Roberts et al. 2016) and mussels (Roberts et al. 2015). Solan et al. (2016) also reported behavioral effects on sediment-dwelling invertebrates during sound exposure. Activities directly contacting the seabed would be expected to have localized impacts on invertebrates and fishes that use the benthic habitat. A risk assessment of the potential impacts of airgun surveys on marine invertebrates and fish in Western Australia concluded that the greater the intensity of sound and the shallower the water, the greater the risk to these animals (Webster et al. 2018). In water >250 m deep, the impact of seismic surveying on fish and marine invertebrates was assessed as acceptable, while in water <250 m deep, risk ranged from negligible to severe, depending on depth, resource-type, and sound intensity (Webster et al. 2018). Immobile organisms, such as molluscs, were deemed to be the invertebrates most at risk from seismic impacts.

4.1.2.1 Effects of Sound on Marine Invertebrates

Effects of anthropogenic sounds on marine invertebrates are varied, ranging from no overt reactions to behavioral/physiological responses, injuries, or mortalities (Aguilar de Soto 2016; Edmonds et al. 2016; Carroll et al. 2017; Weilgart 2017b; Elliott et al. 2019). The available information suggests that invertebrates, particularly crustaceans, may be relatively resilient to airgun sounds (Day et al. 2016a,b).

Fields et al. (2019) conducted laboratory experiments to study effects of exposure to airgun sound on the mortality, predator escape response, and gene expression of the copepod *Calanus finmarchicus* and concluded that the airgun sound had limited effects on the mortality and escape responses of copepods exposed within 10 m of the airgun source but no measurable impact beyond that distance. McCauley et al.

(2017) conducted a 2-day study to examine the potential effects of sound exposure of a 150 in^3 airgun on zooplankton off the coast of Tasmania; they concluded that exposure to airgun sound decreased zooplankton abundance compared to control samples and caused a two- to three-fold increase in adult and larval zooplankton mortality. They observed impacts on the zooplankton as far as 1.2 km from the exposure location – a much greater impact range than previously thought; however, there was no consistent decline in the proportion of dead zooplankton as distance increased and received levels decreased. The conclusions by McCauley et al. (2017) were based on a relatively small number of zooplankton samples, and more replication is required to increase confidence in the study findings.

Richardson et al. (2017) presented results of a modeling exercise intended to investigate the impact of exposure to airgun sound on zooplankton over a much larger temporal and spatial scale than that employed by McCauley et al. (2017). The exercise modeled a hypothetical survey over an area 80 km by 36 km during a 35-day period. Richardson et al. (2017) postulated that the decrease in zooplankton abundance observed by McCauley et al. (2017) could have been due to active avoidance behavior by larger zooplankton. The modeling results did indicate that there would be substantial impact on the zooplankton populations at a local spatial scale but not at a large spatial scale; zooplankton biomass recovery within the exposure area and out to 15 km occurred 3 days after completion of the seismic survey.

Fewtrell and McCauley (2012) exposed captive squid (*Sepioteuthis australis*) to pulses from a single airgun; the received sound levels ranged from 120–184 dB re 1 dB re 1 $\mu Pa^2 \cdot s$ SEL. Increases in alarm responses were seen at SELs >147–151 dB re 1 $\mu Pa^2 \cdot s$; the squid were seen to discharge ink or change their swimming pattern or vertical position in the water column. Solé et al. (2013a,b) exposed four cephalopod species held in tanks to low-frequency (50–400 Hz) sinusoidal wave sweeps (with a 1-s sweep period for 2 h) with received levels of 157 ± 5 dB re 1 µPa and peak levels up to 175 dB re 1 µPa. Besides exhibiting startle responses, all four species examined received damage to the statocyst, which is the organ responsible for equilibrium and movement. The animals also showed stressed behavior, decreased activity, and loss of muscle tone (Solé et al. 2013a). To examine the contribution from near-field particle motion from the tank walls on the study, Solé et al. (2017) exposed common cuttlefish (*Sepia officinalis*) in cages in their natural habitat to 1/3 octave bands with frequencies centered at 315 Hz and 400 Hz and levels ranging from 139–141 re 1 μPa^2. The study animals still incurred acoustic trauma and injury to statocysts, despite not being held in confined tanks with walls.

When New Zealand scallop (*Pecten novaezelandiae*) larvae were exposed to recorded seismic pulses, significant developmental delays were reported, and 46% of the larvae exhibited body abnormalities; it was suggested that the malformations could be attributable to cumulative exposure (Aguilar de Soto et al. 2013). Their experiment used larvae enclosed in 60-mL flasks suspended in a 2-m diameter by 1.3-m water depth tank and exposed to a playback of seismic sound at a distance of 5–10 cm.

There have been several *in situ* studies that have examined the effects of seismic surveys on scallops. Although most of these studies showed no short-term mortality in scallops (Parry et al. 2002; Harrington et al. 2010; Przeslawski et al. 2016, 2018), one study (Day et al. 2016a,b, 2017) did show adverse effects including an increase in mortality rates. Przeslawski et al. (2016, 2018) studied the potential impacts of an industrial seismic survey on commercial (*Pecten fumatus*) and doughboy (*Mimachlamys asperrima*) scallops. *In situ* monitoring of scallops took place in the Gippsland Basin, Australia, using dredging, and autonomous underwater vehicle deployment before the seismic survey, as well as two, and ten months after the survey. The airgun array used in the study was a single 2530 in^3 array made up of 16 airguns operating at 2000 psi with a maximum SEL of 146 dB re 1 $\mu Pa^2 \cdot s$ at 51 m depth. Overall, there was little to no detectable impact of the seismic survey on scallop health as measured by scallop shell size, adductor muscle diameter, gonad size, or gonad stage (Przeslawski et al. 2016). No scallop mortality related to airgun sounds was detected two or ten months after the seismic survey (Przeslawski et al. 2016, 2018).

Day et al. (2016a,b, 2017) exposed scallops (*P. fumatus*) and egg-bearing female spiny lobsters (*Jasus edwardsi*) at a location 10–12 m below the surface to airgun sounds. The airgun source was started ~1–1.5 km from the study subjects and passed over the animals; thus, the scallops and lobsters were exposed to airgun sounds as close as 5–8 m away and up to 1.5 km from the source. Three different airgun configurations were used in the field: 45 in^3, 150 in^3 (low pressure), and 150 in^3 (high pressure), each with maximum peak-to-peak source levels of 191–213 dB re 1 μPa; maximum cumulative SEL source levels were 189–199 dB re 1 $\mu Pa^2 \cdot s$. Exposure to seismic sound was found to significantly increase mortality in the scallops, especially over a chronic time scale (i.e., months post-exposure), although not beyond naturally occurring rates of mortality (Day et al. 2017). Non-lethal effects were also recorded, including changes in reflex behavior time, other behavioral patterns, haemolymph chemistry, and apparent damage to statocysts (Day et al. 2016b, 2017). However, the scallops were reared in suspended lantern nets rather than their natural environment, which can result in higher mortality rates compared to benthic populations (Yu et al. 2010). The female lobsters were maintained until the eggs hatched; no significant differences were found in the quality or quantity of larvae for control versus exposed subjects, indicating that the embryonic development of spiny lobster was not adversely affected by airgun sounds (Day et al. 2016a,b). No mortalities were reported for either control or exposed lobsters (Day et al. 2016a,b). When Day et al. (2019) exposed rock lobster to the equivalent of a full-scale commercial seismic survey passing within 100–500 m, lobsters exhibited impaired righting and damage to the sensory hairs of the statocyst.

Fitzgibbon et al. (2017) also examined the impact of airgun exposure on spiny lobster through a companion study to the Day et al. (2016a,b, 2017) studies; the same study site, experimental treatment methodologies, and airgun exposures were used. The objectives of the study were to examine the haemolymph biochemistry and nutritional condition of groups of lobsters over a period of up to 365 days post-airgun exposure. Overall, no mortalities were observed across both the experimental and control groups; however, lobster total haemocyte count decreased by 23–60% for all lobster groups up to 120 days post-airgun exposure in the experimental group when compared to the control group. A lower haemocyte count increases the risk of disease through a lower immunological response. The only other haemolyph parameter that was significantly affected by airgun exposure was the Brix index of haemolymph at 120 and 365 days post-airgun exposure in one of the experiments involving egg-laden females. Other studies conducted in the field have shown no effects on Dungeness crab larvae or snow crab embryos to seismic sounds (Pearson et al. 1994; DFO 2004b; Morris et al. 2018).

Payne et al. (2015) undertook two pilot studies which (i) examined the effects of a seismic airgun recording in the laboratory on lobster (*Homerus americanus*) mortality, gross pathology, histopathology, serum biochemistry, and feeding; and (ii) examined prolonged or delayed effects of seismic air gun pulses in the laboratory on lobster mortality, gross pathology, histopathology, and serum biochemistry. For experiment (i), lobsters were exposed to peak-to-peak and root-mean-squared received sound levels of 180 dB re 1 μPa and 171 dB re 1 μPa_{rms} respectively. Overall, there was no mortality, loss of appendages, or other signs of gross pathology observed in exposed lobster. No differences were observed in haemolymph, feeding, ovary histopathology, or glycogen accumulation in the heptapancreas. The only observed differences were greater degrees of tubular vacuolation and tubular dilation in the hepatopancreas of the exposed lobsters. For experiment (ii), lobsters were exposed to 20 airgun shots per day for five successive days in a laboratory setting. The peak-to-peak and root-mean-squared received sound levels ranged from ~176–200 dB re 1 μPa and 148–172 dB re 1 μPa_{rms}, respectively. The lobsters were returned to their aquaria and examined after six months. No differences in mortality, gross pathology, loss of appendages, hepatopancreas/ovary histopathology or glycogen accumulation in the hepatopancreas were observed between exposed and control lobsters. The only observed difference was a slight statistically significant difference for calcium-protein concentration in the haemolymph, with lobsters in the exposed group having a lower concentration than the control group.

Celi et al. (2013) exposed captive red swamp crayfish (*Procambarus clarkia*) to linear sweeps with a frequency range of 0.1–25 kHz and a peak amplitude of 148 dB re 1 µPa$_{rms}$ at 12 kHz for 30 min. They found that the noise exposure caused changes in the haemato-immunological parameters (indicating stress) and reduced agonistic behaviors. Wale et al. (2013a,b) showed increased oxygen consumption and effects on feeding and righting behavior of shore crabs when exposed to ship sound playbacks.

Leite et al. (2016) reported observing a dead giant squid (*Architeuthis dux*) while undertaking marine mammal observation work aboard a seismic vessel conducting a seismic survey in offshore Brazil. The seismic vessel was operating 48-airgun array with a total volume of 5085 in^3. As no further information on the squid could be obtained, it is unknown whether the airgun sounds played a factor in the death of the squid.

Heyward et al. (2018) monitored corals *in situ* before and after exposure to a 3-D seismic survey; the maximum SEL and SPL $_{0\text{-pk}}$ were 204 dB re 1 µPa^2·s and 226 dB re 1 µPa. No macroscopic effects on soft tissues or the skeleton were noted days or months after the survey.

4.1.2.2 Effects of Sound on Fish

Popper et al. (2019a) recently reviewed the hearing ability of fishes, and potential impacts of exposure to airgun sound on marine fishes have been reviewed by Popper (2009), Popper and Hastings (2009a,b), Fay and Popper (2012), Weilgart (2017b), Hawkins and Popper (2018), Popper et al. (2019b), and Slabbekoorn et al. (2019); they include pathological, physiological, and behavioral effects. Radford et al. (2014) and Putland et al. (2017) noted that masking of key environmental sounds or social signals could also be a potential negative effect from sound. Popper et al. (2014) presented guidelines for seismic sound level thresholds related to potential effects on fish. The effect types discussed include mortality, mortal injury, recoverable injury, temporary threshold shift, masking, and behavioral effects. Seismic sound level thresholds were discussed in relation to fish without swim bladders, fish with swim bladders, and fish eggs and larvae. Hawkins and Popper (2017) cautioned that particle motion as well as sound pressure should be considered when assessing the effects of underwater sound on fishes.

Bruce et al. (2018) studied the potential behavioral impacts of a seismic survey in the Gippsland Basin, Australia, on three shark species: tiger flathead (*Neoplatycephalus richardsoni*), gummy shark (*Mustelus antarcticus*), and swellshark (*Cephaloscylum laticeps*). Sharks were captured and tagged with acoustic tags before the survey and monitored for movement via acoustic telemetry within the seismic area. The energy source used in the study was a 2530 in^3 array consisting of 16 airguns with a maximum SEL of 146 dB re 1 µPa^2·s at 51 m depth. Flathead and gummy sharks were observed to move in and around the acoustic receivers while the airguns in the survey were active; however, most sharks left the study area within 2 days of being tagged. The authors of the study did not attribute this behavior to avoidance, possibly because the study area was relatively small. Overall, there was little conclusive evidence of the seismic survey impacting shark behavior, though flathead shark did show increases in swim speed that was regarded by the authors as a startle response to the airguns operating within the area.

Peña et al. (2013) used an omnidirectional fisheries sonar to determine the effects of a 3-D seismic survey off Vesterålen, northern Norway, on feeding herring (*Clupea harengus*). They reported that herring schools did not react to the seismic survey; no significant changes were detected in swimming speed, swim direction, or school size when the drifting seismic vessel approached the fish from a distance of 27 km to

2 km over a 6-h period. Peña et al. (2013) attributed the lack of response to strong motivation for feeding, the slow approach of the seismic vessel, and an increased tolerance to airgun sounds.

Miller and Cripps (2013) used underwater visual census to examine the effect of a seismic survey on a shallow-water coral reef fish community in Australia. The census took place at six sites on the reef before and after the survey. When the census data collected during the seismic program were combined with historical data, the analyses showed that the seismic survey had no significant effect on the overall abundance or species richness of reef fish. This was in part attributed to the design of the seismic survey (e.g., ≥400 m buffer zone around reef), which reduced the impacts of seismic sounds on the fish communities by exposing them to relatively low SELs (<187 dB re 1 $\mu Pa^2 \cdot s$).

Fewtrell and McCauley (2012) exposed pink snapper (*Pagrus auratus*) and trevally (*Pseudocaranx dentex*) to pulses from a single airgun; the received sound levels ranged from 120–184 dB re 1 dB re 1 $\mu Pa^2 \cdot s$ SEL. Increases in alarm responses were seen in the fish at SELs >147–151 dB re 1 $\mu Pa^2 \cdot s$; the fish swam faster and formed more cohesive groups in response to the airgun sounds.

Hastings and Miksis-Olds (2012) measured the hearing sensitivity of caged reef fish following exposure to a seismic survey in Australia. When the auditory evoked potentials (AEP) were examined for fish that had been in cages as close as 45 m from the pass of the seismic vessel and at water depth of 5 m, there was no evidence of TTS in any of the fish examined, even though the cumulative SELs had reached 190 dB re 1 $\mu Pa^2 \cdot s$.

Davidsen et al. (2019) outfitted Atlantic cod and saithe with acoustic transmitters to monitor their behaviors (i.e., swimming speed, movement in water column) in response to exposure to seismic airgun sound. The study was conducted in Norway using a large sea cage with a 30 m diameter and 25 m depth. Both sound pressure and particle motion were measured within the sea cage. An airgun firing every 10 s was towed toward the sea cage from an initial distance of 6.7 km from the cage to a minimum distance of 100 m from the cage. The SEL_{cum} ranged from 172–175 dB re 1 $\mu Pa^2 \cdot s$. Both the cod and saithe changed swimming depth and horizontal position more frequently during exposure to the sound. The saithe became more dispersed in response to elevated sound levels. Both species exhibited behavioral habituation to the repeated exposures to sound.

Radford et al. (2016) conducted experiments examining how repeated exposures of different sounds to European seabass (*Dicentrarchus labrax*) can reduce the fishes' response to that sound. They exposed post-larval seabass to playback recordings of seismic survey sound (single strike SEL 144 dB re 1 $\mu Pa^2 \cdot s$) in large indoor tanks containing underwater speakers. Their findings indicated that short-term exposure of seismic sound increased the ventilation rate (i.e., opercular beat rate [OBR]) of seabass that were not previously exposed to seismic relative to seabass in controlled, ambient sound conditions. Fish that were reared in tanks that were repeatedly exposed to seismic sound over a 12-week period exhibited a reduced OBR response to that sound type, but fish exposed over the same time period to pile-driving noise displayed a reduced response to both seismic and pile-driving noise. An increased ventilation rate is indicative of greater stress in seabass; however, there was no evidence of mortality or effects on growth of the seabass throughout the 12-week study period.

Popper et al. (2016) conducted a study that examined the effects of exposure to seismic airgun sound on caged pallid sturgeon (*Scaphirhynchus albus*) and paddlefish (*Polyodon spathula*); the maximum received peak SPL in this study was 224 dB re 1 µPa. Results of the study indicated no mortality, either during or seven days after exposure, and no statistical differences in effects on body tissues between exposed and control fish.

Andrews et al. (2014) conducted functional genomic studies on the inner ear of Atlantic salmon (*Salmo salar*) that had been exposed to seismic airgun sound. The airguns had a maximum SPL of ~145 dB re 1 μPa^2/Hz and the fish were exposed to 50 discharges per trial. The results provided evidence that fish exposed to seismic sound either increased or decreased their expressions of different genes, demonstrating that seismic sound can affect fish on a genetic level.

Sierra-Flores et al. (2015) examined broadcast sound as a short-term stressor in Atlantic cod (*Gadus morhua*) using cortisol as a biomarker. An underwater loudspeaker emitted SPLs ranging from 104–110 dB re 1 μPa_{rms}. Plasma cortisol levels of fish increased rapidly with sound exposure, returning to baseline levels 20–40 min post-exposure. A second experiment examined the effects of long-term sound exposure on Atlantic cod spawning performance. Tanks were stocked with male and female cod and exposed daily to six noise events, each lasting one hour. The noise exposure had a total SPL of 133 dB re 1 µPa. Cod eggs were collected daily and measured for egg quality parameters as well as egg cortisol content. Total egg volume, floating fraction, egg diameter and egg weight did not appear to be negatively affected by sound exposure. However, fertilization rate and viable egg productivity were reduced by 40% and 50%, respectively, compared with the control group. Mean egg cortisol content was found to be 34% greater in the exposed group as compared to the control group. Elevated cortisol levels inhibit reproductive physiology for males and can result in a greater frequency of larval deformities for spawning females.

4.1.2.3 Effects of Sound on Fisheries

Handegard et al. (2013) examined different exposure metrics to explain the disturbance of seismic surveys on fish. They applied metrics to two experiments in Norwegian waters, during which fish distribution and fisheries were affected by airguns. Even though the disturbance for one experiment was greater, the other appeared to have the stronger SEL, based on a relatively complex propagation model. Handegard et al. (2013) recommended that simple sound propagation models should be avoided and that the use of sound energy metrics like SEL to interpret disturbance effects should be done with caution. In this case, the simplest model (exposures per area) best explained the disturbance effect.

Hovem et al. (2012) used a model to predict the effects of airgun sounds on fish populations. Modeled SELs were compared with empirical data and were then compared with startle response levels for cod. This work suggested that in the future, particular acoustic-biological models could be useful in designing and planning seismic surveys to minimize disturbance to fishing. Their preliminary analyses indicated that seismic surveys should occur at a distance of 5–10 km from fishing areas, in order to minimize potential effects on fishing.

In their introduction, Løkkeborg et al. (2012) described three studies in the 1990s that showed effects on fisheries. Results of a study off Norway in 2009 indicated that fishes reacted to airgun sound based on observed changes in catch rates during seismic shooting; gillnet catches increased during the seismic shooting, likely a result of increased movement of exposed fish, whereas longline catches decreased overall (Løkkeborg et al. 2012).

Streever et al. (2016) completed a Before-After/Control-Impact (BACI) study in the nearshore waters of Prudhoe Bay, Alaska in 2014 which compared fish catch rates during times with and without seismic activity. The air gun arrays used in the geophysical survey had sound pressure levels of 237 dB re 1$\mu Pa_{0\text{-}p}$, 243 dB re 1$\mu Pa_{p\text{-}p}$, and 218 dB re 1μPa_{rms}. Received SPL_{max} ranged from 107–144 dB re 1 µPa, and received SEL_{cum} ranged from 111–141 dB re 1μPa^2-s for air gun pulses measured by sound recorders at four fyke net locations. They determined that fyke nets closest to air gun activities showed decreases in catch per unit effort (CPUE) while nets further away from the air gun source showed increases in CPUE.

Bruce et al. (2018) studied the potential impacts of an industrial seismic survey in the Gippsland Basin, Australia, on catches in the Danish seine and gillnet fishing sectors for 15 fish species. Catch data were examined from three years before the seismic survey to six months after completion of the survey in an area 13,000 km^2. Overall, there was little evidence of consistent adverse impacts of the seismic survey on catch rates. Six of the 15 species were found to have increased catch rates.

Paxton et al. (2017) examined the effects of seismic sounds on the distribution and behavior of fish on a temperate reef during a seismic survey conducted in the Atlantic Ocean on the inner continental shelf of North Carolina. Hydrophones were set up near the seismic vessel path to measure SPLs, and a video camera was set up to observe fish abundances and behaviors. Received SPLs were estimated at ~202–230 dB re 1 µPa. Overall abundance of fish was lower when undergoing seismic activity as opposed to days when no seismic occurred. Only one fish was observed to exhibit a startle response to the airgun shots. The authors claim that although the study was based on limited data, it contributes evidence that normal fish use of reef ecosystems is reduced when they are impacted by seismic sounds.

Morris et al. (2018) conducted a two-year (2015–2016) BACI study examining the effects of 2-D seismic exploration on catch rates of snow crab (*Chionoecetes opilio*) along the eastern continental slope (Lilly Canyon and Carson Canyon) of the Grand Banks of Newfoundland, Canada. The airgun array used was operated from a commercial seismic exploration vessel; it had a total volume of 4880 in^3, horizontal zero-to-peak SPL of 251 dB re 1 µPa, and SEL of 229 dB re 1 µPa^2·s. The closest approach of the survey vessel to the treatment site in 2015 (year 1 of the study) was 1465 m during 5 days of seismic operations; in 2016 (year 2), the vessel passed within 100 m of the treatment site but the exposure lasted only 2 h. Overall, the findings indicated that the sound from the commercial seismic survey did not significantly reduce snow crab catch rates during days or weeks following exposure. Morris et al. (2018) attributed the natural temporal and spatial variations in the marine environment as a greater influence on observed differences in catch rates between control and experimental sites than exposure to seismic survey sounds.

4.1.2.4 Conclusions for Invertebrates, Fish, Fisheries, EFH, and HAPC

The newly available information does not affect the outcome of the effects assessment as presented in the PEIS. The PEIS concluded that there could be changes in behavior and other non-lethal, short-term, temporary impacts, and injurious or mortal impacts on a small number of individuals within a few meters of a high-energy acoustic source, but that there would be no significant impacts of NSF-funded marine seismic research on populations. The PEIS also concluded that seismic surveys could cause temporary, localized reduced fish catch to some species, but that effects on fisheries would not be significant.

Interactions between the proposed surveys and fishing operations in the study area are expected to be limited. Two possible conflicts in general are R/V *Langseth*'s streamer entangling with fishing gear and the temporary displacement of fishers from the survey area. Fishing activities could occur within the proposed survey area; a safe distance would need to be kept from R/V *Langseth* and the towed seismic equipment. Conflicts would be avoided through communication with the fishing community during the surveys. PSOs would also watch for any impacts the acoustic sources may have on fish during the survey.

Given the proposed activities, impacts would not be anticipated to be significant or likely to adversely affect (including ESA-listed) marine invertebrates, marine fish (Table 11), and their fisheries, including commercial, recreational, and subsistence fisheries. Additionally, no mortality of fish or marine invertebrates are expected in marine reserves along the coast of Oregon, as the injury threshold distances would not enter the reserves that are at least 2 km away. In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, R/V *Ewing*, PSOs and other crew members have not observed any seismic sound-related fish or invertebrate injuries or mortality. During a similar survey conducted in the region in

TABLE 11. ESA determination for DPSs or ESUs of fish species expected to be encountered during the proposed surveys in the Northeast Pacific Ocean during late spring/summer 2021.

	ESA Determination		
		May Affect –	May Affect –
Species	**No Effect**	**Not Likely to Adversely Affect**	**Likely to Adversely Affect**
Bocaccio (Puget Sound/Georgia Basin DPS)		√	
Yelloweye Rockfish (Puget Sound/Georgia Basin DPS)		√	
Steelhead Trout (Various DPSs)		√	
Bull trout (Coastal Puget Sound DPS)		√	
Chinook Salmon (Various ESUs)		√	
Chum Salmon (Various ESUs)		√	
Coho Salmon (Various ESUs)		√	
Sockeye Salmon (Various ESUs)		√	
Pacific Eulachon (Southern DPS)		√	
Green Sturgeon (Southern DPS)		√	
Giant Manta Ray	√		
Oceanic Whitetip Shark	√		
Scalloped Hammerhead Shark (Eastern Pacific DPS)	√		

the past (Marine Geophysical Surveys by R/V *Marcus G. Langseth* in the Northeastern Pacific Ocean, June–July 2012), there were no observed significant impacts. In addition, no adverse effects on EFH or HAPC are expected given the short-term nature of the study (~40 days) and minimal bottom disturbance

4.1.3 Direct Effects on Seabirds and Their Significance

The underwater hearing of seabirds (including loons, scaups, gannets, and ducks) has recently been investigated, and the peak hearing sensitivity was found to be between 1500 and 3000 Hz (Crowell 2016). The best sensitivity of underwater hearing for great cormorants was found to be at 2 kHz, with a hearing threshold of 71 dB re 1 μPa_{rms} (Hansen et al. 2017). Great cormorants were also found to respond to underwater sounds and may have special adaptations for hearing underwater (Johansen et al. 2016; Hansen et al. 2017). African penguins (*Spheniscus demersus*) outfitted with GPS loggers showed strong avoidance of preferred foraging areas and had to forage farther away and increase their foraging effort when a seismic survey was occurring within 100 km of the breeding colony (Pichegru et al. 2017). However, the birds resumed their normal behaviors when seismic operations concluded.

Potential effects of seismic sound and other aspects of seismic operations (collisions, entanglement, and ingestion) on seabirds are discussed in § 3.5.4 of the PEIS. The PEIS concluded that there could be transitory disturbance, but that there would be no significant impacts of NSF-funded marine seismic research on seabirds or their populations. If an injury threshold of 202 dB SEL is assumed, then the radius around the airgun array within which diving birds could sustain injury is 84 m. However, no activities would occur within 8 km from shore, where most marbled murrelets are found. In addition, the acoustic source would be powered or shut down in the event an ESA-listed seabird was observed diving or foraging within the designated EZ (500 m for power down, 100 m for shut down). Given the proposed activities and their limited occurrence in the proposed project area, impacts would not be anticipated to be significant or likely to adversely affect most seabird species, including short-tailed albatross and Hawaiian petrel (Table 12). Based on an analysis and consultation with USFWS, the marbled murrelet is likely to be adversely affected, but the proposed activities are not likely to jeopardize the continued existence of the marbled murrelet. In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, the R/V *Ewing*, PSOs and other crew members have seen no seismic sound-related seabird injuries or mortality.

TABLE 12. ESA determination for seabird species expected to be encountered during the proposed surveys in the Northeast Pacific Ocean during late spring/summer 2021.

	ESA Determination		
Species	No Effect	May Affect – Not Likely to Adversely Affect	May Affect – Likely to Adversely Affect
Short-tailed Albatross		√	
Hawaiian Petrel		√	
Marbled Murrelet			√

4.1.4 Indirect Effects on Marine Mammals, Sea Turtles, Seabirds and Fish and Their Significance

The proposed seismic operations would not result in any permanent impact on habitats used by marine mammals, sea turtles, seabirds, or fish or to the food sources they use. The main impact issue associated with the proposed activity would be temporarily elevated anthropogenic sound levels and the associated direct effects on these species, as discussed above.

During the proposed seismic surveys, only a small fraction of the available habitat would be ensonified at any given time. Disturbance to fish species and invertebrates would be short-term, and fish would return to their pre-disturbance behavior once the seismic activity ceased. Thus, the proposed surveys would have little impact on the abilities of marine mammals or sea turtles to feed in the area where seismic work is planned. No significant indirect impacts on marine mammals, sea turtles, seabirds, or fish would be expected.

4.1.5 Direct Effects on Tribal & First Nation Fisheries, Cultural Resources, and Their Significance

The coast and nearshore areas are of cultural importance to indigenous peoples for fishing (including subsistence and commercial), hunting, gathering, and ceremonial purposes. As noted above in Section 4.1.2.4, impacts would not be anticipated to be significant or likely to adversely affect marine invertebrates, marine fish, and their fisheries, including subsistence fisheries. Less than 2 days of survey operations are planned within all U&A fisheries, with some areas affected for only a few hours. Interactions between the proposed surveys and fishing operations in the study area are expected to be limited. Although fishing would not be precluded in the survey area, a safe distance would need to be kept from R/V *Langseth* and the towed seismic equipment. Conflicts would be avoided through Notice to Mariners and direct radio communication with subsistence fishers during the surveys. When finalized, NSF would provide survey start date and route plans within the U&A fisheries to tribal points of contact and give notice three days in advance of planned operations within U&A fisheries.

Additionally, there are thousands of shipwrecks along the coast of the Pacific Northwest from Oregon to B.C. However, the proposed activities are of short duration (~40 days), and most of the shipwrecks (and dive sites) are located in shallower water outside of the project area. Conflicts would be avoided through communication with dive operators during the surveys. Furthermore, OBSs and OBNs would be deployed to avoid shipwrecks and would only cause minimal seafloor disturbances. Therefore, no adverse impacts to cultural resources are anticipated.

4.1.6 Cumulative Effects

Cumulative effects refer to the impacts on the environment that result from a combination of past, existing, and reasonably foreseeable projects and human activities. Cumulative effects can result from multiple causes, multiple effects, effects of activities in more than one locale, and recurring events. Human activities, when conducted separately or in combination with other activities, could affect marine animals in the study area. However, understanding cumulative effects is complex because of the animals' extensive habitat ranges, and the difficulty in monitoring populations and determining the level of impacts that may result from certain activities.

According to Nowacek et al. (2015), cumulative impacts have a high potential of disturbing marine mammals. Wright and Kyhn (2014) proposed practical management steps to limit cumulative impacts, including minimizing exposure by reducing exposure rates and levels. Models of cumulative effects that incorporate all threats to resident killer whales are better at predicting demographic rates of population than individual threat models (Lacy et al. 2017; Murray et al. 2019).

The results of the cumulative impacts analysis in the PEIS indicated that there would not be any significant cumulative effects to marine resources from the proposed NSF-funded marine seismic research, including the combined use of airguns with MBES, SBP, and acoustic pingers. However, the PEIS also stated that, "A more detailed, cruise-specific cumulative effects analysis would be conducted at the time of the preparation of the cruise-specific EAs, allowing for the identification of other potential activities in the areas of the proposed seismic surveys that may result in cumulative impacts to environmental resources." Here we focus on activities (e.g., research, vessel traffic, and fisheries) that could impact animals specifically in the proposed survey area. However, the combination of the proposed surveys with the existing operations in the region would be expected to produce only a negligible increase in overall disturbance effects on marine mammals.

4.1.6.1 Past, Current, and Future Research Activities

Scripps Institution of Oceanography (SIO) conducted low-energy seismic surveys for ~4–7 days off the coast of Oregon/Washington during September 2007, July 2009, and September 2017. During July 2008, UTIG conducted a low-energy seismic survey for ~6 days off the coast of Oregon. In June–August 2004 and August–October 2005, the riserless drilling vessel *JOIDES Resolution* conducted coring off OR. Seismic surveys using a 36-airgun array were conducted in the EVH MPA, to the north of the proposed survey area, by R/V *Langseth* during summer 2009, and off the coast of Oregon/Washington during June–July 2012.

NSF funded the Cascadia Initiative (CI), an ambitious onshore/offshore seismic and geodetic experiment that took advantage of an amphibious array to study questions ranging from megathrust earthquakes, to volcanic arc structure, to the formation, deformation, and hydration of the Juan De Fuca and Gorda Plates (Toomey et al. 2014). CI involved a plate-scale seismic experiment that encompassed components of the Cascadia subduction zone as well as the underthrusting Juan de Fuca Plate. The onshore seismic component of the amphibious array consisted of the EarthScope USArray Transportable Array and the offshore seismic component consisted of OBSs. Over four field seasons from 2011–2014, oceanographic expeditions and OBSs deployments and recoveries were conducted in the region to collect data in support of the research objectives. As noted previously, an onshore research effort is also currently under consideration for NSF funding which would complement the proposed R/V *Langseth* activities. The proposed onshore component would vastly expand upon the marine-based dataset, providing a more complete geophysical dataset for the Cascadia region.

During May–June 2018, SIO conducted vibracoring and CHIRP profiles off the Oregon coast, and retrieved seafloor receivers collecting magnetotelluric and passive seismic data offshore OR utilizing R/V *Roger Revelle*. SIO deployed geodetic transponders from R/V *Roger Revelle* along the Cascadia Subduction Zone off Oregon during June 2018, which were later retrieved. During June–August 2018, SIO conducted a cabled array survey offshore Oregon using the remote operated vehicle (ROV) *Jason* and R/V

Roger Revelle. As a component of this survey, a shallow profiler was installed and an ROV was deployed from R/V *Thompson* to turn instruments and/or moorings during July/August 2018. R/V *Sally Ride* was used by SIO to conduct biological sampling to assess mesozooplankton food webs off Oregon and northern California during July 2018, and deploy coastal surface moorings off Oregon and Washington during September–October 2018. SIO utilized two vessels to conduct sampling for a primary production study in the waters off the Northwest Pacific during August–September 2018, and collected atmospheric, water column and surficial sediment samples along 152ºW from Alaska to Tahiti using R/V *Roger Revelle* during September–October and October–November 2018.

The Northwest Fisheries Science Center conducts the West Coast Groundfish Bottom Trawl Survey from May to October every year, covering the area twice (NOAA 2021b). The survey takes place from Cape Flattery to the U.S./Mexico border (NOAA 2021b). These surveys are conducted to assess 90 commercially fished stocks to ensure sustainable fisheries (NOAA 2021b).

The Oregon State University will be conducting a whale study off the coast of Oregon that is funded by the U.S. Office of Naval Research. The study will include the deployment of two hydrophones – one off Otter Rock Marine Reserve and the other just to the southwest of Newport. All activities associated with the study would occur within 16 km from shore. In addition, the PacWave development route and area is also located within 16 km from shore off Oregon. PacWave is an open ocean wave energy test facility located off Newport.

NSF has funded a research project focused on (1) measuring particle motion and pressure from the survey and (2) behavioral responses of important marine species: rockfishes (*Sebastes* spp.), Dungeness crab, and longnose skate. The study, to be carried out by researchers from Oregon State University, would occur concurrently with the seismic survey off the coast of Oregon.

The U.S. portion of the proposed survey area is the site of numerous other recent studies including of fluid seeps along the margin, and recent (2018 and 2019) as well as future high-resolution seismic studies by the USGS as part of their multi-year hazard assessment studies for the Pacific Northwest. There are also ongoing studies using the Ocean Observatories Initiative (OOI) regional cable underwater volcanic observatory, including nodes at Axial Seamount, Juan de Fuca Plate, Hydrate Ridge, and on the Oregon shelf. In addition to having an active volcano which erupted in 1998, 2011, and 2015, Axial Seamount has several hydrothermal fields (OOI 2018). Numerous geophysical, chemical, and biological sensors, as well as cameras, are deployed there, which provide real-time information on seismic events via a cabled array (OOI 2018).

Drilling as a component of the Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) was undertaken during 1971, 1992, and 2002 off Oregon (IODP 2019). Drilling was also conducted off B.C. and Washington during several ODP legs from 1991–1996, and in 2010, as a component of the IODP (IODP 2019). In addition, the IODP is proposing to drill at locations to be sited on the proposed seismic lines (IODP 2019).

In addition, Ocean Networks Canada hosts NEPTUNE (North East Pacific Time-series Underwater Networked Experiments), an underwater fiber-optic cabled observatory network in the waters of B.C. This network consists of a 840-km loop of fibre optic cable with five nodes, located at Folger Passage (near Barkley Sound), Barkley Canyon, Clayoquot Sound, Cascadia Basin, and Endeavour Ridge (Ocean Networks Canada 2019a). Instrumentation at each node includes acoustic doppler current profilers, current meters, hydrophones, rotary sonars, bottom pressure recorders, video cameras, temperature probes, oxygen sensors, and LED lights (Ocean Networks Canada 2019b).

DFO and the Canadian Groundfish Research and Conservation Society (CGRCS) conduct regular surveys in B.C. to provide fishery independent abundance indices of all demersal fish species available to bottom trawling along the B.C. coast (DFO 2018e). A large-scale survey of marine megafauna off the coast of B.C. was undertaken by DFO during July to September 2018, as well as expeditions to offshore seamounts during July 2018 and July 2019 (DFO 2019d). At the Endeavour MPA, research projects, mainly by foreign vessels (4–7 per year) and Canadian Coast Guard (1–2 per year) vessels are undertaken (Conley 2006). The SWFSC conducts regular marine mammal surveys off the U.S. coast, including off Oregon/Washington. Other research activities may have been conducted in the past or may be conducted in the study area in the future; however, we are not aware of any research activities, in addition to the OOI, that are planned to occur in the proposed project area during late spring/summer 2021.

4.1.6.2 Naval Activities

In summer 2012, the U.S. Navy conducted a test sponsored by the Naval Sea Systems Command, who is responsible for the research, development, and construction of Navy systems. They tested a towed array with an active acoustic source and a passive receiver. The primary test took place during both a north and south ship transit between San Diego, CA, and Puget Sound, WA, in the Pacific Northwest, when the ship was >12 nmi (~22 km) from the coast of the U.S. The Rose Festival Fleet Week occurs annually during October, for which visiting U.S. Navy ships (e.g., destroyers and mine countermeasure ships) and fleet-related elements (e.g., submarines) transit to Portland, OR (PRFF 2019). Seafair annually hosts visiting vessels from the U.S. Navy, U.S. Coast Guard, and Royal Canadian Navy during Fleet Week and the Boeing Maritime Celebration during July/August on the Seattle, WA, waterfront (Seafair 2018). Navy vessels may transit within or near the proposed survey area during any given year while travelling to west coast Fleet Week ports, depending on a ship's originating location. Other Navy activities may have been or may be conducted in this region in the future as this area is included in the U.S. Navy's Northwest Training and Testing Area, which extends up to 250 nmi offshore; however, we are not aware of any specific activities that are planned to occur in the proposed survey area during late spring/summer 2021.

4.1.6.3 Vessel Traffic

Several major ports are located on the northwestern coast of the U.S., including Seattle, Tacoma, and Portland, as well as Vancouver, B.C., and major shipping lanes originate there. Vessel traffic in the proposed survey area would consist mainly of commercial fishing and cargo vessels. Based on the data available through the Automate Mutual-Assistance Vessel Rescue (AMVER) system managed by the U.S. Coast Guard (USCG), most of the shipping lanes that intersect the survey area had 4 or fewer vessels travelling along them on a monthly basis during June–July 2019 (USCG 2019). At least 150 vessels occurred within the proposed survey area when live vessel traffic information (MarineTraffic 2019) was accessed on 1 October 2019; vessels mainly consisted of fishing vessels, but also included pleasure crafts, cruise ships, cargo vessels, tankers, and tugs. The total transit time by R/V *Langseth* (~40 days) would be minimal relative to the number of other vessels operating in the proposed survey area during late spring/summer 2021. Thus, the combination of R/V *Langseth*'s operations with the existing shipping operations is expected to produce only a negligible increase in overall ship disturbance effects on marine mammals.

4.1.6.4 Fisheries Interactions

The commercial fisheries in the region are described in § III. The primary contributions of fishing to potential cumulative impacts on marine mammals and sea turtles involve direct and indirect removal of prey items, sound produced during fishing activities, and potential entanglement (Reeves et al. 2003).

***Marine mammals*.—**According to Lewison et al. (2014), the northwest coast of the U.S. has relatively high bycatch rates for marine mammals. Between 1990 and 1996, an average of 456 cetaceans and 160 pinnipeds were killed or seriously injured per year in the California/Oregon driftnet fishery. As a result of regulatory action to reduce cetacean bycatch in 1997, bycatch was reduced to a yearly average of 105 cetaceans (8 odontocete species and fin, minke, and gray whales) and 77 pinnipeds (California sea lion and northern elephant seal) during the 1997–2006 period (Moore et al. 2009). Before 2000, high bycatch of harbor porpoises, southern sea otters, and pinnipeds (California sea lion, harbor seals, and elephant seals) occurred in the set gillnet fishery for California halibut. The bycatch likely led to the decline of the harbor porpoise. Restrictions applied between 2000 and 2002 effectively closed most of the fishery (Moore et al. 2009). In 2009, based on observed bycatch, the estimated total bycatch in the California/Oregon large-mesh drift gillnet fishery for thresher sharks and swordfish was 7 short-beaked common dolphins, 15 Pacific white-sided dolphins, and 37 California sea lions (Carretta and Enriquez 2010).

Three fisheries had marine mammal takes in the non-Pacific hake groundfish fisheries from 2002–2005 (NMFS 2008c). An estimated 250 marine mammals were killed in the limited-entry bottom trawl fishery; bycatch estimates included 227.6 California sea lions, 11.5 Steller sea lions, 7.5 Pacific white-sided dolphins, and 3.1 harbor porpoises (NMFS 2008c). Bycatch in the limited-entry sablefish fishery was estimated at 29 California sea lions. Eight California sea lions were also killed in the non-sablefish endorsed fishery during the same period (NMFS 2008c). A number of pinnipeds were also caught in the west coast Pacific hake fishery; estimated bycatch for 2002–2006 included 2.5 harbor seals, 8.3 Steller sea lions, 6.9 California sea lions, and 3.4 elephant seals (NMFS 2008c). During 2007–2009, bycatch totals for the U.S. west coast groundfish fishery included 19 California sea lions, 12 Steller sea lions, 12 northern elephant seals, 5 harbor seals, 1 Risso's dolphin, 1 bottlenose dolphin, and 1 sperm whale (Jannot et al. 2011). The extent of bycatch is unknown in some fisheries that receive little or no observer coverage. In 2005, ~87 short-beaked common dolphins were killed in squid purse seines; an estimated 5196 other marine mammals were caught but released alive across all other observed California purse seine fisheries (Carretta and Enriquez 2006). In 2005, the bycatch for the Northwest Region (including Oregon) for the sablefish-endorsed fixed gear, groundfish bottom trawl, and mid-water hake trawl fisheries was estimated at 37 animals, including 33.7 California sea lions, 2.4 Steller sea lions, and 1.2 harbor seals (NMFS 2011b). From 2010–2014, Carretta et al. (2016) reported 85 large whales and 116 small cetaceans entangled in fishing gear for the U.S. west coast; there were 180 cases of pinniped injuries and mortalities in the hook and line fishery.

Canada's Pacific groundfish bottom trawl fishery operates off the B.C. coast; during 1996–2006 the following marine mammals were caught and discarded: Steller sea lions (50 incidents), northern fur seals (1 incident), California sea lions (3) , harbor seals (16), northern elephant seal (1), eared seals and walruses (6), other pinnipeds (32), Pacific white-sided dolphins (5), common dolphins (1), and unidentified porpoises and dolphins (8) (Driscoll et al. 2009). Entanglement in fishing gear, and fishery-caused reduction in prey abundance, quality, and availability have been identified as threats to blue, fin, and sei whales (Gregr et al. 2006) and Pacific harbor porpoise (COSEWIC 2016a). Between 1987 and 2008, there were 40 reports of humpbacks entangled in fishing gear in B.C.; humpbacks were entangled in gear from gillnet fisheries (salmon, herring roe), trap fisheries (crab, prawn, sablefish), groundfish long-line fisheries, and seine fisheries (Ford et al. 2009). Inshore fisheries in B.C. are also known to by-catch Pacific white-sided dolphins, harbor porpoises, and Dall's porpoises (Stacey et al. 1997; Williams et al. 2008).

***Sea turtles*.**—According to Lewison et al. (2014) and Roe et al. (2014), the northwest coast of the U.S. has relatively low bycatch rates for sea turtles. Finkbeiner et al. (2011) reported that between 1990 and 2007, the annual mean bycatch for sea turtles in the California/Oregon driftnet fishery was 30 individuals before regulations came into effect, and <10 after regulations were put in place. Moore et al. (2009) reported that an average of 14 leatherbacks were killed annually in the California/Oregon drift gillnet fishery before regulations were implemented to reduce bycatch in 1997 and 2001. There was no bycatch reported for 2005 (NMFS 2011b). One sea turtle (a leatherback in 2008) was killed or injured in the west coast groundfish fishery in 2002–2009 off California (Jannot et al. 2011). Carretta and Enriquez (2010) reported one leatherback caught and released alive in 2009.

***Seabirds*.—**According to Lewison et al. (2014), the northwest coast of the U.S. has relatively low bycatch rates for seabirds. Net fisheries for salmon in Puget Sound have killed thousands of birds annually, mostly murres and auklets (Moore et al. 2009). Annual seabird bycatch in the set net fishery for California halibut during 1990–2001 ranged from 308–3259; most bycatch consisted of common murres, loons, grebes, and cormorants (Moore et al. 2009). Closure of the central California fishery in depths <110 m in 2002 reduced bycatch to an estimated 61 seabirds in 2003 (Moore et al. 2009). The estimated take of seabirds in the non-Pacific hake fisheries during 2002–2005 totaled 575, half of which were common murres. Other species caught included Leach's storm petrel, Brandt's cormorant, black-footed albatross, western gull, and brown pelican (NMFS 2008c). Jannot et al. (2011) reported takes of 11 seabird species in the west coast groundfish fishery during 2002–2009, including marbled murrelets and short-tailed albatross; in 2009, northern fulmars made up most of the bycatch. The estimated take of seabirds in the Pacific hake fisheries during the same period was 50 birds, including seven black-footed albatrosses, five common murres, 23 northern fulmars, two sooty shearwaters, and 13 unidentified seabirds (NMFS 2008c). In 2005, the bycatch for the Northwest Region (including Oregon) was estimated at 106 birds for the west coast groundfish limited entry non-trawl, groundfish bottom trawl, and mid-water hake trawl fisheries, including 58.8 black-footed albatross, 35.6 brown pelicans, 3.8 gulls, 2 sooty shearwaters, 2 northern fulmars, 2 common murres, and 2 unidentified seabirds (NMFS 2011b). Smith and Morgan (2005) estimated that 12,085 seabirds were bycaught annually in the commercial gillnet fishery in B.C. between 1995 and 2001, of which 95% succumbed.

4.1.6.5 Tourism

Various companies offer whale and dolphin watching off the coast of Oregon and Washington. Whale watching can occur in this area year-round (Oregon Coast Visitors Association 2019). The main focus of the whale watch industry is the southward gray whale migration from mid-December through January and their northbound migration from March–June (Oregon Coast Visitors Association 2019). However, some whales are resident off Oregon in the summer and can be seen there from June through November (Oregon Coast Visitors Association 2019). There are at least 11 whale watching boat charters along the coast of Oregon, including at Newport and Depoe Bay; whale watching flights are also carried out by at least six companies (Oregon Coast Visitors Association 2019). Whale watching also takes place in Washington State, but most of the excursions occur near the San Juan Islands and inshore of the proposed project area. Whalewatch operations also occur in B.C. waters, including in the Strait of Juan de Fuca and off the west coast of Vancouver Island, from ports such as Port Renfrew, Tofino, and Ucluelet.

4.1.6.6 Whaling and Sealing

There is limited whaling and sealing by indigenous groups in the Pacific Northwest. In the U.S., the Makah Tribe has historically hunted gray whales; in recent times, a gray whale was successfully hunted on 17 May 1999 (NOAA 2015). NOAA has recently released a proposed rule to allow a limited hunt for gray whales by the Makah Tribe (NOAA 2019l). NOAA is currently considering a plan to cull sea lions on the Columbia River in order to benefit salmonid populations; under this plan, federal employees as well as indigenous tribes would remove sea lions (NOAA 2019m). In Canada, various First Nations harvest seals and sea lions, and some indigenous groups are advocating pinniped culls to benefit salmonid stocks.

4.1.7 Unavoidable Impacts

Unavoidable impacts to the species of marine mammals and turtles occurring in the proposed survey area would be limited to short-term, localized changes in behavior of individuals. For marine mammals, some of the changes in behavior may be considered to fall within the MMPA definition of "Level B Harassment" (behavioral disturbance; no serious injury or mortality). TTS, if it occurs, would be limited to a few individuals, is a temporary phenomenon that does not involve injury, and is unlikely to have long term consequences for the few individuals involved. No long-term or significant impacts would be expected on any of these individual marine mammals or turtles, or on the populations to which they belong; NMFS, however, requires NSF to request Level A takes. Effects on recruitment or survival would be expected to be (at most) negligible.

4.1.8 Coordination with Other Agencies and Processes

This Final EA has been prepared by LGL on behalf of L-DEO and NSF pursuant to NEPA and Executive Order 12114. Potential impacts to marine mammals, endangered species, and critical habitat have also been assessed in the document. The Draft EA was used to support the ESA Section 7 consultation process with NMFS and USFWS and other regulatory processes, such as the EFH and CZMA. Due to their involvement with the Proposed Action, the USGS also agreed to be a Cooperating Agency. The Draft EA was also used as supporting documentation for an IHA application submitted by L-DEO to NMFS and USFWS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals, for the proposed seismic survey. NSF sent notices to potential interested parties and posted the Draft EA on the NSF website for a 30-day public comment period from 7 February 2020 to 7 March 2020; comments were received from three entities (Center for Biological Diversity, Oregon Department of Fish and Game, a private individual) and are addressed in Appendix E. NSF sent letters to tribal contacts to notify the tribes of the Proposed Action and NSF's related environmental compliance review, including the availability of the Draft EA, and also to provide an opportunity to consult. NSF discussed the project with a point of contact from the Quinault Nation. NSF understands a letter was sent from the Makah Tribe to NSF highlighting some points of concern about the project; however, the letter was unfortunately not received by the agency. NSF has coordinated with a point of contact on the matter.

NSF coordinated with NMFS to complete the Final EA prior to issuance of an IHA and Biological Opinion/ITS to accommodate NMFS' need to adopt NSF's Final EA as part of the NMFS NEPA process associated with issuing authorizations. NSF had enhanced coordination with NMFS and USFWS throughout the IHA and ESA consultation processes to facilitate this streamlined approach. NSF also coordinated with DFO. NSF, the researchers, and L-DEO coordinated with the Navy and fishers to avoid space-use conflicts and/or security matters.

(a) Endangered Species Act (ESA)

The Draft EA was used during the ESA Section 7 consultation process with NMFS and USFWS. On 22 November 2019, NSF submitted a letter of concurrence request to USFWS that the proposed activity may affect but was not likely to adversely affect the ***endangered*** Hawaiian petrel and short-tailed albatross, and the ***threatened*** marbled murrelet. On 11 January 2020, USFWS provided a letter of concurrence (Appendix F) that the proposed activity "may affect" but was not likely to "adversely affect" the Hawaiian petrel and short-tailed albatross, but did not concur for marbled murrelet, requesting additional information related to this species. In subsequent discussions with USFWS, they also identified that the Proposed Action could have potential effects on bull trout. On 24 March 2020, NSF provided additional information to USFWS on marbled murrelet and bull trout and held subsequent discussions on these species. NSF notified USFWS on 29 May 2020 that the proposed survey would be deferred until spring/summer 2021 due to COVID impacts and unfinalized federal regulatory processes, including the USFWS processes. On 5 June 2020, NSF requested the consultation efforts be continued and concluded in a timely manner despite the deferral; an extension of the consultation period was not requested or agreed upon. NSF contacted USFWS on numerous subsequent occasions to request a status update and to complete the consultation; however, USFWS demonstrated no progress in concluding the consultation. A meeting with both agency management staff was held to address the matter on 26 February 2021. On 12 April 2021, USFWS issued a Biological Opinion on these species to NSF noting that the proposed action may affect, but is not likely to adversely affect the bull trout and its critical habitat, and that the proposed actions is likely to adversely affect but is not likely to jeopardize the continued existence of the marbled murrelet (Appendix F). Mitigation measures for ESA-listed seabirds would include power downs, and if necessary, shut downs for diving or foraging seabirds within the EZ.

On 8 November 2019, NSF submitted a formal ESA Section 7 consultation request, including the Draft EA, to NMFS for the proposed activity. NSF and NMFS held bi-weekly meetings to discuss the ESA consultation. NMFS conducted tribal outreach efforts consistent with *Secretarial Order (#3206): American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act*, to help inform their consultation on this action. Letters were sent to tribes with potential interest in the consultation. On 17 February 2021, NMFS held a webinar to discuss the project, including participation from representatives of tribes, NSF, and OCNMS. Per the request of the tribal representative attendees, an additional meeting focused on potential tribal fisheries interactions was held on 6 April 2021; NSF participated in the meeting.

On 3 March 2021, NOAA received a letter from the Makah Tribal Council outlining their general support of the project but making several requests, including that NSF (1) notify Makah Fisheries Management when the survey start date is finalized with route plans and anticipated dates of surveys within the Makah U&A fishing area, as well as three days in advance of reaching the Makah U&A; (2) adopt the enhanced mitigation measure to restrict seismic survey operations to daylight hours and include a second observer vessel within the Makah U&A fishing area regardless of depth to better ensure that ESA-listed marine mammals are identified and avoided; and (3) identify opportunities to monitor for acoustic impacts associated with the seismic surveys and make this data available to Makah Fisheries Management. NOAA, with input from NSF, provided a response to the Makah Tribe on 21 April 2021. The Makah Tribe also requested government to government consultation with NOAA; however, later it was communicated that a consultation meeting with NOAA Fisheries was not needed.

As previously noted, NSF had enhanced coordination with NMFS during the consultation process. Based on this enhanced coordination, NSF anticipates that a Biological Opinion and ITS will be issued for the proposed activity. As part of its decision-making process for the Proposed Action, NSF will take into consideration the Biological Opinion and ITS issued by NMFS and the results of the entire environmental review process.

(b) Marine Mammal Protection Act (MMPA)

The Draft EA was also used as supporting documentation for an IHA application submitted on 8 November 2019 by L-DEO on behalf of itself, NSF, and the researchers, to NMFS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals during the proposed seismic survey. NSF and NMFS held bi-weekly meetings to discuss the IHA application. On 7 April 2019, NMFS issued in the Federal Register a notice of intent to issue an IHA for the survey and a 30-day public comment period. Public comments were received from three entities during that process, including the Center for Biological Diversity, Ecojustice, and Deep Green Wilderness; NMFS considered the comments and will provide responses as required per the IHA process. As previously noted, NSF had enhanced coordination with NMFS and USFWS during the IHA application process. Based on this enhanced coordination, NSF anticipates that an IHA will be issued for the proposed activity. As part of its decision-making process for the Proposed Action, NSF will take into consideration the IHA issued by NMFS and the results of the entire environmental review process.

The Draft EA was also used as supporting documentation for an IHA application submitted on 20 December 2019 by L-DEO on behalf of itself, NSF, and the researchers, to USFWS, under the U.S. MMPA, for “taking by harassment” (disturbance) of small numbers of marine mammals during the proposed seismic survey. NSF had additional dialog and correspondence with USFWS regarding the IHA application, including providing additional supplemental information. After discussions with USFWS staff, NSF agreed to eliminate survey tracklines near sea otter habitat, including most activities within the 100 m isobath. NSF notified USFWS on 29 May 2020 that the proposed survey would be deferred until spring/summer 2021 due to COVID impacts and unfinalized federal regulatory processes, including the USFWS IHA process. On 5 June 2020, NSF requested the IHA application continue to be processed in a timely manner despite the deferral. On 1 March 2021, USFWS issued in the Federal Register a notice of intent to issue an IHA for the survey and a 30-day public comment period (Appendix D). Public comments were received from three entities during that process, including from the Marine Mammal Commission; USFWS considered the comments and will provide responses as required per the IHA process. USFWS issued an IHA for the proposed activity on 20 April 2021 (Appendix D). As part of its decision-making process for the Proposed Action, NSF has taken into consideration the IHA issued by USFWS and the results of the entire environmental review process.

(c) Coastal Zone Management Act (CZMA)

On 20 December 2019, NSF submitted a determination that the Proposed Action was consistent to the maximum extent practicable with the enforceable policies of Oregon’s Coastal Zone Management Program. On 4 March 2020, the Oregon Department of Land Conservation and Development confirmed presumed concurrence with the NSF determination that the proposed activity is consistent to the maximum extent practicable with the enforceable policies of Oregon’s CZM Program (Appendix G). During this process, some concerns were raised related to potential space-use conflicts with fishers; however, as noted in Section 4.1.2.4 and 4.1.5, NSF anticipates limited space-use conflict with fishers. Outreach efforts and coordination with members of the fishing industry have occurred to help further reduce any potential space-use conflicts. For example, the researchers have prepared and plan to distribute flyers and digital maps of the proposed tracklines and OBS/OBN deployments to the fishing community to avoid conflicts, including fishing gear stores in Oregon coastal towns. During operations, the vessels would communicate with other ocean users via Notice to Mariners and radio communications. Researchers engaged with the commercial fishing community through organizations like the Oregon Fishermen’s Cable Committee (OFCC) and the Scientists and Fishermen Exchange (SAFE) Program from Oregon Sea Grant. As a result of researcher participation in OFCC virtual meetings, the survey vessel operator is exploring whether Automatic Identification System (AIS) can be added to the streamer tail buoy.

On 8 January 2020, NSF submitted a determination that the Proposed Action was consistent to the maximum extent practicable with the enforceable policies of Washington’s Coastal Zone Management Program. On 23 March 2020, the State of Washington Department of Ecology, pursuant to the Coastal Zone Management Act of 1972 as amended, concurred with NSF’s determination that the proposed work is consistent with Washington’s CZMP, and that NSF demonstrated that the proposed action is consistent with the CZMP’s enforceable policies found in Washington’s Ocean Resource’s Management Act and the Ocean Management Guidelines, which call for no long-term significant impacts to Washington’s coastal zone resources or uses (Appendix G).

(d) National Marine Sanctuary Act/Olympic Coast National Marine Sanctuary

On 19 December 2019, LDEO submitted a permit application to OCNMS for activities that would occur within the Sanctuary. A Sanctuary Resource Statement (SRS) was submitted to the Office of National Marine Sanctuaries (ONMS) on 16 March 2020 by NSF and NMFS. After the survey originally scheduled for 2020 was deferred, the permit was updated for the spring/summer 2021 timeframe and resubmitted to OCNMS on 15 June 2020. As part of the permit process, OCNMS also sought input on the application from the Hoh, Makah, Quileute, and Quinault Tribes. On 19 May 2020, Quileute Tribe submitted comments on the permit application to OCNMS. In particular, the Tribe stated that they did not support the abandonment of any equipment in the marine environment, including the OBS anchors. No OBSs or anchors would be deployed within the Quileute Tribal U&A Fisheries. Based on this input, however, NSF modified the originally proposed plan to use within the Sanctuary steel anchors for the OBSs to concrete anchors, which while still cannot be retrieved, should degrade faster and mainly to sand.

NSF contacted OCNMS on multiple occasions to inquire about the status of the SRS and permit. After requesting additional information in January 2021, a revised SRS was submitted on 22 January 2021. ONMS found, on 27 January 2021, that the SRS was sufficient to make an injury determination. In their final determination dated 12 March 2021, ONMS made two alternative recommendations to further minimize injury and protect sanctuary resources: (1) limit operations in OCNMS to daylight hours only regardless of depth, and (2) use of the secondary support vessel aiding in marine mammal observations throughout the entire sanctuary (Appendix H). On 19 March 2021, NSF notified OCNMS the alternative recommendations were accepted and understood no further consultation with OCNMS was necessary prior to conducting the Proposed Action. OCNMS issued the permit on 2 April 2021 (Appendix H).

(e) Essential Fish Habitat (EFH)

EFH and HAPCs were identified to occur within the proposed survey area. Although NSF anticipated no significant impacts to EFH and HAPC, as the Proposed Action may affect EFH and HAPC, in accordance with the Magnuson-Stevens Fishery Conservation and Management Act, NSF requested consultation with NMFS on 14 November 2019. In discussions with NMFS, it was determined to incorporate the EFH process into the ESA consultation.

(f) Canadian Department of Fisheries and Oceans

An application for a Species at Risk permit application was submitted on 19 December 2019. After discussion with DFO staff, the Species at Risk application was revised and resubmitted along with a Fisheries Act Request for Review on 18 December 2020. After consultation with DFO, all proposed transect lines and their associated 160-dB ensonified area were moved out of Canadian critical habitat for southern resident killer hales. On 6 April 2021, DFO issued a Letter of Advice with measures to follow to avoid causing the death of fish (including marine mammals) and/or harmful alteration, disruption, or destruction of fish habitat, or causing prohibited effects to SARA species, any part of their critical habitat or the residences of their individuals (Appendix J). The most stringent measures presented in either the DFO letter or the IHA to be issued by NMFS would be implemented within the Canadian EEZ. In addition, L-DEO and NSF would comply with DFO's "Measurement measures to protect southern resident killer whales", and the "Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment", as much as practicable and where these measures are more stringent than required by DFO or NMFS.

4.2 No Action Alternative

An alternative to conducting the proposed activity is the "No Action" Alternative, i.e., do not issue an IHA and do not conduct the operations. If the research were not conducted, the "No Action" alternative would result in no disturbance to marine mammals or sea turtles attributable to the proposed activity; however, valuable data about the marine environment would be lost. Research that would contribute to our understanding of the Cascadia Subduction Zone, providing new constraints on earthquake and tsunami potential in this heavily populated region of the Pacific Northwest. would not be collected. The No Action Alternative would not meet the purpose and need for the proposed activity.

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LIST OF APPENDICES

Appendix A: Determination of Mitigation Zones

APPENDIX A: DETERMINATION OF MITIGATION ZONES

During the planning phase, mitigation zones for the proposed marine seismic survey were calculated based on both modeling by L-DEO for the Level A and Level B (160 dB re $1\mu Pa_{rms}$) thresholds and using empirical measurements from Crone et al. (2014) from the Cascadia Margin. Received sound levels have been predicted by L-DEO's model (Diebold et al. 2010, provided as Appendix H in the PEIS) as a function of distance from the 36-airgun array and for a single 1900LL 40-in^3 airgun, which would be used during power downs; all models used a 12-m tow depth. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor). In addition, propagation measurements of pulses from the 36-airgun array at a tow depth of 6 m have been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the Gulf of Mexico (GoM) in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

Typically for deep and intermediate-water cases, the field measurements cannot be used readily to derive mitigation radii, as at those sites the calibration hydrophone was located at a roughly constant depth of 350–500 m, which may not intersect all the sound pressure level (SPL) isopleths at their widest point from the sea surface down to the maximum relevant water depth for marine mammals of ~2000 m (Costa and Williams 1999). Figures 2 and 3 in Appendix H of the PEIS show how the values along the maximum SPL line that connects the points where the isopleths attain their maximum width (providing the maximum distance associated with each sound level) may differ from values obtained along a constant depth line. At short ranges, where the direct arrivals dominate and the effects of seafloor interactions are minimal, the data recorded at the deep and slope sites are suitable for comparison with modeled levels at the depth of the calibration hydrophone. At longer ranges, the comparison with the mitigation model—constructed from the maximum SPL through the entire water column at varying distances from the airgun array—is the most relevant. The results are summarized below.

In deep and intermediate-water depths, comparisons at short ranges between sound levels for direct arrivals recorded by the calibration hydrophone and model results for the same array tow depth are in good agreement (Fig. 12 and 14 in Appendix H of the PEIS). Consequently, isopleths falling within this domain can be predicted reliably by the L-DEO model, although they may be imperfectly sampled by measurements recorded at a single depth. At greater distances, the calibration data show that seafloor-reflected and sub-seafloor-refracted arrivals dominate, whereas the direct arrivals become weak and/or incoherent (Fig. 11, 12, and 16 in Appendix H of the PEIS). Aside from local topography effects, the region around the critical distance (~5 km in Fig. 11 and 12, and ~4 km in Fig. 16 in Appendix H of the PEIS) is where the observed levels rise closest to the mitigation model curve. However, the observed sound levels are found to fall almost entirely below the mitigation model curve (Fig. 11, 12, and 16 in Appendix H of the PEIS). Thus, analysis of the GoM calibration measurements demonstrates that although simple, the L-DEO model is a robust tool for conservatively estimating mitigation radii. In shallow water (<100 m), the depth of the calibration hydrophone (18 m) used during the GoM calibration survey was appropriate to sample the maximum sound level in the water column, and the field measurements reported in Table 1 of Tolstoy et al. (2009) can be scaled for the single airgun at a tow depth of 6 m to derive mitigation radii.

L-DEO collected a multichannel seismic (MCS) data set from R/V *Langseth* on an 8 km streamer in 2012 on the shelf of the Cascadia Margin in water up to 200 m deep that allowed Crone et al. (2014) to analyze the hydrophone streamer (>1100 individual shots). These empirical data were then analyzed to determine in situ sound levels for shallow and upper intermediate water depths to provide mitigation radii.

This analysis is summarized in the Addendum at the end of this Appendix. Similarly, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that *in situ* measurements and estimates of the 160- and 180-dB distances collected by R/V *Langseth* hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels[8] have confirmed that the L-DEO model generated conservative threshold distances, resulting in significantly larger mitigation zones than required by National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS).

The proposed surveys would acquire data with the 36-airgun array at a maximum tow depth of 12 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m (Fig. A-1; Table A-1). The radii for the shallow and intermediate water depths are taken from the empirical data from Crone et al. (2014) and corrected for tow depth (ie., multiplied by 1.15; see Addendum). Similarly, 175 dB_{RMS} distances have been determined using the same methodology and are provided in Table A-1. Measurements have not been reported for the single 40-in^3 airgun. L-DEO model results are used to determine the 160-dB_{rms} radius for the 40-in^3 airgun at a 12-m tow depth in deep water (Fig. A-3). For intermediate-water depths, a correction factor of 1.5 was applied to the deep-water model results. For shallow water, a scaling of the field measurements obtained for the 36-airgun array was used. The 150-dB SEL level corresponds to a deep-water radius of 431 m for the 40-in^3 airgun at 12-m tow depth (Fig. A-3) and 7244 for the 36-airgun array at 6-m tow depth (Fig. A-2), yielding a scaling factor of 0.0595. Similarly, the 165-dB SEL level corresponds to a deep-water radius of 77 m for the 40-in^3 airgun at 12-m tow depth (Fig. A-3) and 1284 m for the 36-airgun array at 6-m tow depth (Fig. A-2), yielding a scaling factor of 0.060. The 185-dB SEL level corresponds to a deep-water radius of 7.5 m for the 40-in^3 airgun at 12-m tow depth (Fig. A-3) and 126.3 m for the 36-airgun array at 6-m tow depth (Fig. A-2), yielding a scaling factor of 0.0594. Measured 160- and 175-dB re 1µPa_{rms} distances in shallow water for the 36-airgun array towed at 6-m depth were 17.5 km and 2.8 km, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by the scaling factors to account for the difference in array sizes and tow depths yields distances of 1041 m and 170 m, respectively.

[8] L-DEO surveys off the Yucatán Peninsula in 2004 (Barton et al. 2006; Diebold et al. 2006), in the Gulf of Mexico in 2008 (Tolstoy et al. 2009; Diebold et al. 2010), off Washington and Oregon in 2012 (Crone et al. 2014), and off New Jersey in 2014 and 2015 (Crone et al. 2017).

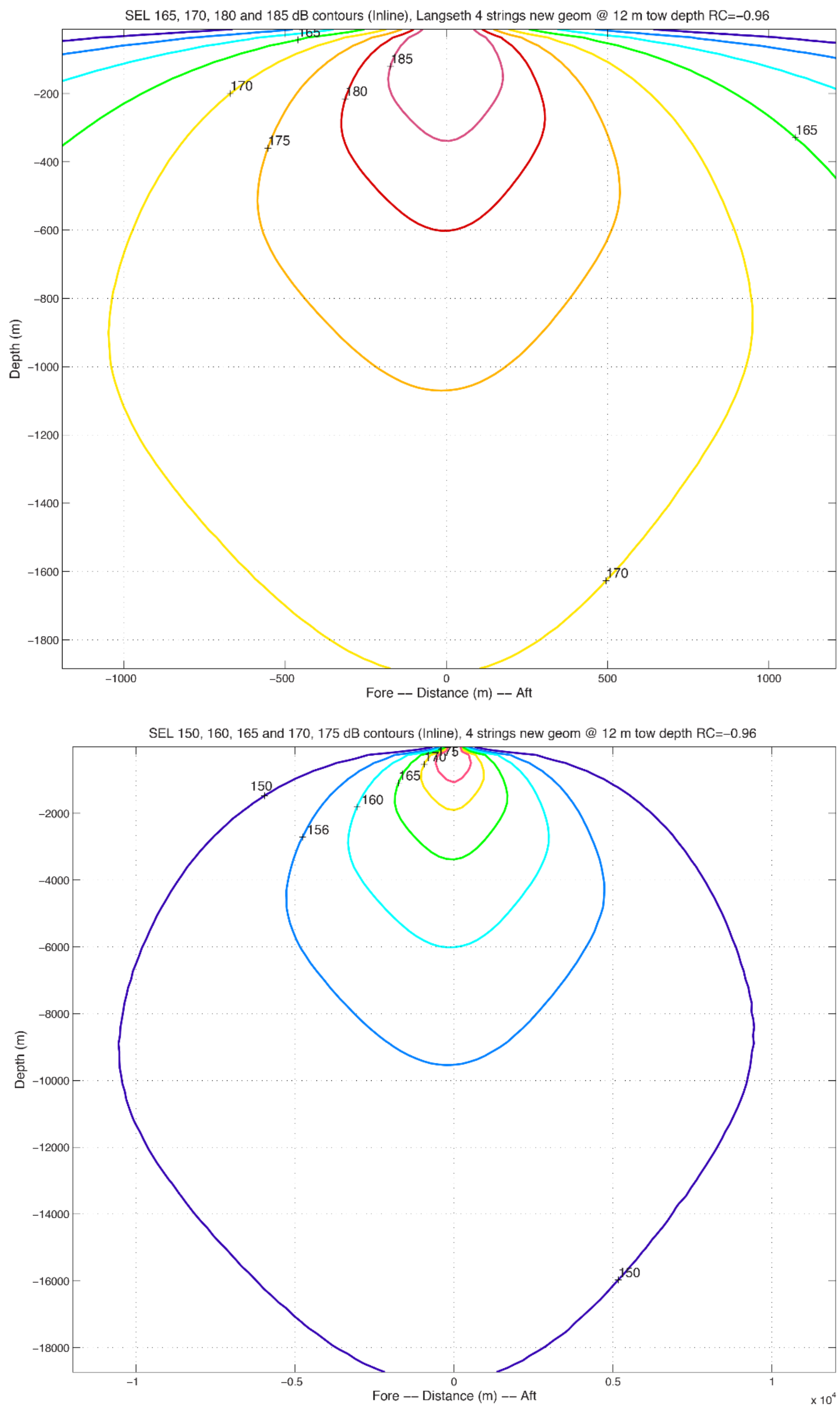


FIGURE A-1. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth planned for use during the proposed surveys in the Northeast Pacific Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

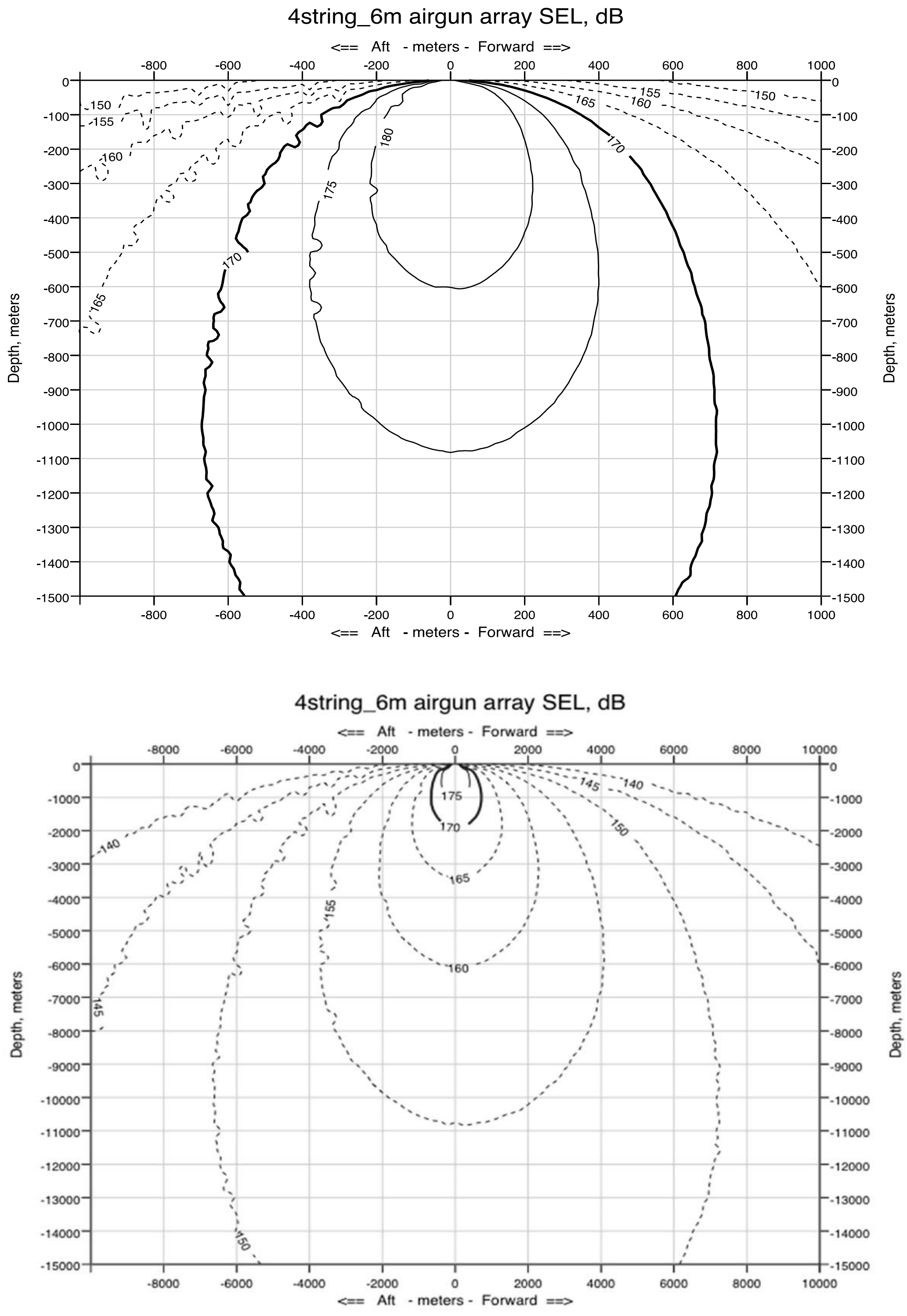
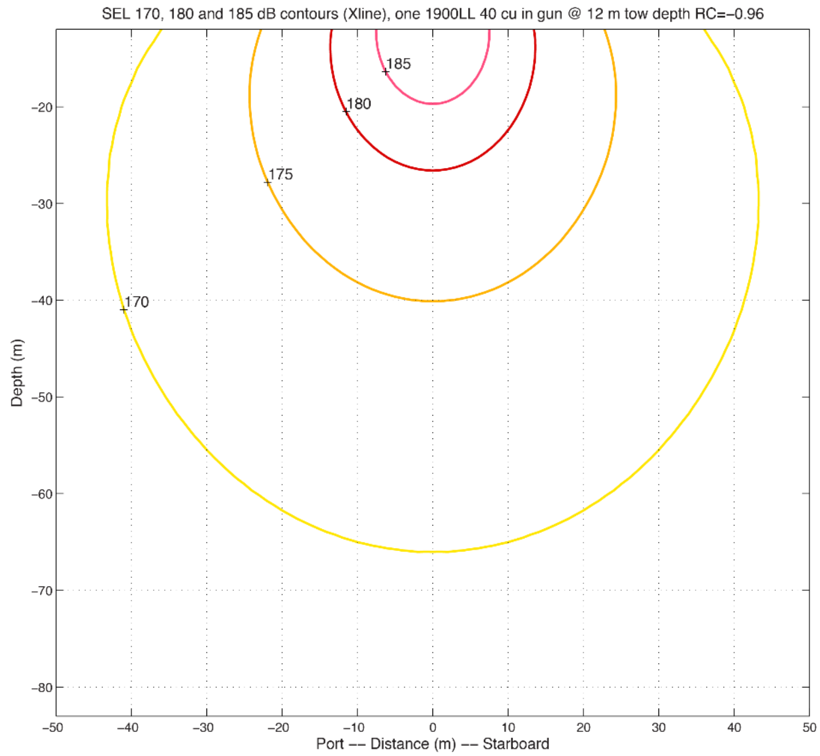


Figure A-2. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150 dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.



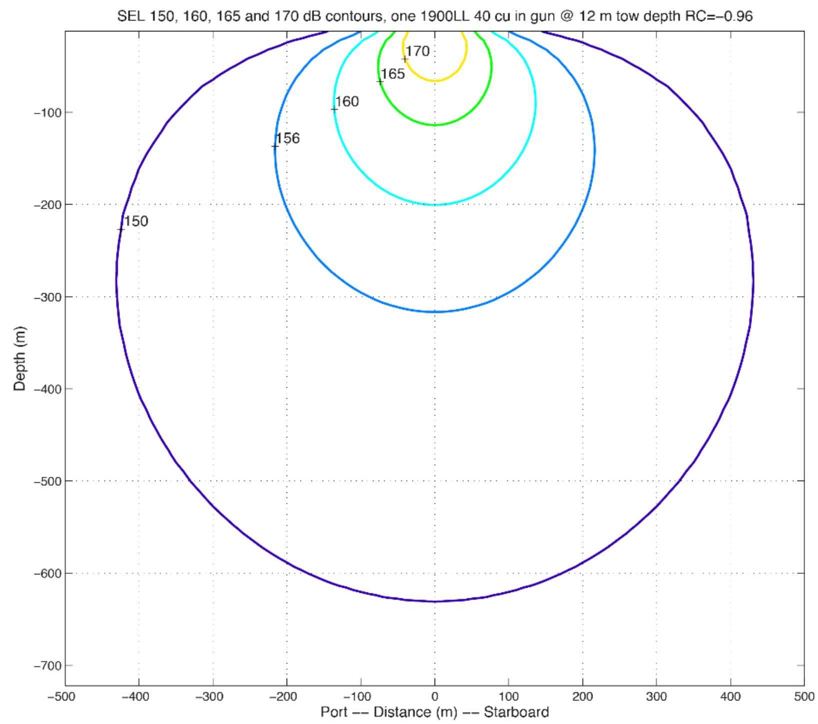


FIGURE A-3. Modeled deep-water received SELs from a single 40-in^3 airgun towed at a 12-m depth, which is planned for use as a mitigation airgun during the proposed surveys in the Northeast Pacific Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. For example, the radius to the 150-dB SEL isopleth is a proxy for the 160-dB rms isopleth. The upper plot is a zoomed-in version of the lower plot.

Table A-1 shows the distances at which the 160-dB and 175-dB re 1µPa$_{rms}$ sound levels are expected to be received for the 36-airgun array and the single (mitigation) airgun. The 160-dB level is the behavioral disturbance criteria (Level B) that is used by NMFS to estimate anticipated takes for marine mammal. The 175-dB level is used by NMFS, based on data from the USN (2017), to determine behavioral disturbance for turtles. A recent retrospective analysis of acoustic propagation of *Langseth* sources in a coastal/shelf environment from the Cascadia Margin off Washington suggests that predicted (modeled) radii (using an approach similar to that used here) for *Langseth* sources were 2–3 times larger than measured in shallow water, so in fact, as expected, were very conservative (Crone et al. 2014). Similarly, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that *in situ* measurements and estimates of the 160- and 180-dB distances collected by the *Langseth* hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels[9] have confirmed that the L-DEO model generated conservative EZs, resulting in significantly larger EZs than required by National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS).

In July 2016, NMFS released technical guidance for assessing the effects of anthropogenic sound on marine mammal hearing (NMFS 2016, 2018). The guidance established new thresholds for permanent threshold shift (PTS) onset or Level A Harassment (injury), for marine mammal species. The new noise exposure criteria for marine mammals account for the newly-available scientific data on temporary threshold shifts (TTS), the expected offset between TTS and PTS thresholds, differences in the acoustic frequencies to which different marine mammal groups are sensitive, and other relevant factors, as summarized by Finneran (2016). For impulsive sources, onset of PTS was assumed to be 15 dB or 6 dB higher when considering SEL$_{cum}$ and SPL$_{flat}$, respectively. The new guidance incorporates marine mammal auditory weighting functions (Fig. A-4) and dual metrics of cumulative sound exposure level (SEL$_{cum}$ over 24 hours) and peak sound pressure levels (SPL$_{flat}$). Different thresholds are provided for the various hearing groups, including low-frequency (LF) cetaceans (e.g., baleen whales), mid-frequency (MF) cetaceans (e.g., most delphinids), high-frequency (HF) cetaceans (e.g., porpoise and *Kogia* spp.), phocids underwater (PW), and otariids underwater (OW). The largest distance of the dual criteria (SEL$_{cum}$ or Peak SPL$_{flat}$) was used to calculate takes and Level A threshold distances. The dual criteria for sea turtles (USN 2017) were also used here. The new NMFS guidance did not alter the current threshold, 160 dB re 1µPa$_{rms}$, for Level B harassment (behavior). Southall et al. (2019) provided updated scientific recommendations regarding noise exposure criteria which are similar to those presented by NMFS (2016, 2018), but include all marine mammals (including sirenians), and a re-classification of hearing groups.

The SEL$_{cum}$ for the *Langseth* array is derived from calculating the modified farfield signature. The farfield signature is often used as a theoretical representation of the source level. To compute the farfield signature, the source level is estimated at a large distance directly below the array (e.g., 9 km), and this level is back projected mathematically to a notional distance of 1 m from the array's geometrical center. However, it has been recognized that the source level from the theoretical farfield signature is never physically achieved at the source when the source is an array of multiple airguns separated in space

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[9] L-DEO surveys off the Yucatán Peninsula in 2004 (Barton et al. 2006; Diebold et al. 2006), in the Gulf of Mexico in 2008 (Tolstoy et al. 2009; Diebold et al. 2010), off Washington and Oregon in 2012 (Crone et al. 2014), and off New Jersey in 2014 and 2015 (Crone et al. 2017).

TABLE A-13. Level B. Predicted distances to which sound levels ≥160-dB and ≥175-dB re 1 μPa_{rms} could be received during the proposed surveys in the Northeast Pacific Ocean. The 160-dB criterion applies to all hearing groups of marine mammals and the 175-dB criterion applies to sea turtles.

Source and Volume	Tow Depth (m)	Water Depth (m)	Predicted distances (in m) to the 160-dB Received Sound Level	Predicted distances (in m) to the 175-dB Received Sound Level
Single Bolt airgun, 40 in^3	12	>1000 m	431[1]	77[1]*
		100–1000 m	647[2]	116[2]
		<100 m	1,041[3]	170[3]
4 strings, 36 airguns, 6600 in^3	12	>1000 m	6,733[1]	1,864[1]
		100–1000 m	9,468[4]	2,542[4]
		<100 m	12,650[4]	3,924[4]

1 Distance is based on L-DEO model results.
2 Distance is based on L-DEO model results with a 1.5 × correction factor between deep and intermediate water depths.
3 Distance is based on empirically derived measurements in the GOM with scaling applied to account for differences in tow depth.
4 Based on empirical data from Crone et al. (2014).
* An EZ of 100 m would be used as the shut-down distance for sea turtles in all water depths.

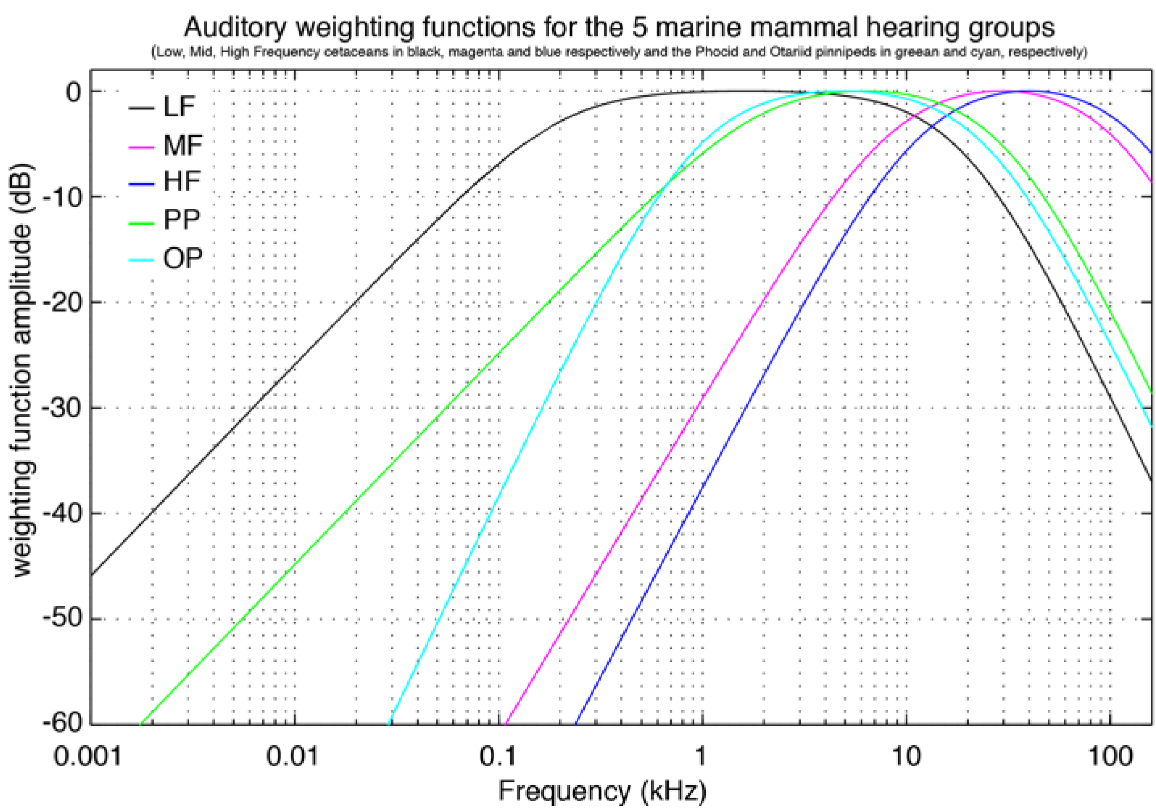

FIGURE A-4. Auditory weighting functions for five marine mammal hearing groups from the NMFS Technical Guidance Spreadsheet.

(Tolstoy et al. 2009). Near the source (at short ranges, distances <1 km), the pulses of sound pressure from each individual airgun in the source array do not stack constructively as they do for the theoretical farfield signature. The pulses from the different airguns spread out in time such that the source levels observed or modeled are the result of the summation of pulses from a few airguns, not the full array (Tolstoy et al. 2009). At larger distances, away from the source array center, sound pressure of all the airguns in the array stack coherently, but not within one time sample, resulting in smaller source levels (a few dB) than the source level derived from the farfield signature. Because the farfield signature does not take into account the large array effect near the source and is calculated as a point source, the farfield signature is not an appropriate measure of the sound source level for large arrays.

To estimate SEL_{cum} and Peak SPL, we used the acoustic modeling developed at L-DEO (same as used for Level B takes) with a small grid step in both the inline and depth directions. The propagation modeling takes into account all airgun interactions at short distances from the source including interactions between subarrays which we do using the NUCLEUS software to estimate the notional signature and the MATLAB software to calculate the pressure signal at each mesh point of a grid.

PTS onset acoustic thresholds estimated in the NMFS User Spreadsheet rely on overriding the default values and calculating individual adjustment factors (dB) based on the modified farfield and by using the difference between levels with and without weighting functions for each of the five categories of hearing groups. The new adjustment factors in the spreadsheet allow for the calculation of SEL_{cum} isopleths in the spreadsheet and account for the accumulation (Safe Distance Methodology) using the source characteristics (source velocity and duty) after Sivle et al. (2014). A source velocity of 2.2 m/s and a 1/Repetition rate of 17.3 s were used as inputs to the NMFS User Spreadsheet for calculating the distances to the SEL_{cum} PTS thresholds (Level A) for the 36-airgun array and the single 40-in^3 mitigation airgun.

For the LF cetaceans, we estimated a new adjustment value by computing the distance from the geometrical center of the source to where the 183 dB SEL_{cum} isopleth is the largest. We first ran the modeling for a single shot without applying any weighting function; we then ran the modeling for a single shot with the LF cetacean weighting function applied to the full spectrum. The difference between these values provides an adjustment factor and assumes a propagation of $20\log_{10}$(Radial distance).

However, for MF and HF cetaceans, and OW and PW pinnipeds, the modeling for a single shot with the weighted function applied leads to 0-m isopleths; the adjustment factors thus cannot be derived the same way as for LF cetaceans. Hence, for MF and HF cetaceans, and OW and PW pinnipeds, the difference between weighted and unweighted spectral source levels at each frequency up to 3 kHz was integrated to actually calculate these adjustment factors in dB. These calculations also account for the accumulation (Safe Distance Methodology) using the source characteristics (duty cycle and speed) after Sivle et al. (2014).

For the 36-airgun array, the results for single shot SEL source level modeling are shown in Table A-2. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds for the 36-airgun array are shown in Table A-3. Figure A-5 shows the impact of weighting functions by hearing group. Figures A-6–A-8 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-9 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans.

TABLE A-2. Results for single SEL source level modeling for the 36-airgun array with and without applying weighting functions to the five marine mammal hearing groups and sea turtles. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest. A propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**185**	**155**	**185**	**203**	**204**
Radial Distance (m) (no weighting function)	315.5691	246.4678	8033.2	246.4678	28.4413	25.1030
Modified Farfield SEL	232.9819	232.8352	233.0978	232.8352	232.0790	231.9945
Radial Distance (m) (with weighting function)	71.3752	N.A.	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-12.91	N.A.	N.A.	N.A.	N.A.	N.A.

* Propagation of 20 log R. N.A. means not applicable or not available.

TABLE A-3. Results for single shot SEL source level modeling for the 36-airgun array with weighting function calculations for the SEL_{cum} criteria, as well as resulting isopleths to thresholds for hearing groups.

STEP 1: GENERAL PROJECT INFORMATION

PROJECT TITLE	
PROJECT/SOURCE INFORMATION Please include any assumptions	Source : 4 string 36 element 6600 cu.in of the R/V Langseth at a 12 m towed depth. Shot inteval of 37.5 m. Source velocity of 4.2 knots
PROJECT CONTACT	

STEP 2: WEIGHTING FACTOR ADJUSTMENT Specify if relying on source-specific WFA, alternative weighting/dB adjustment, or if using default value

Weighting Factor Adjustment (kHz)[¥]	NA	Override WFA: Using LDEO modeling

[¥] Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab

† If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 62), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.

* BROADBAND Sources: Cannot use WFA higher than maximum applicable frequency (See GRAY tab for more information on WFA applicable frequencies)

STEP 3: SOURCE-SPECIFIC INFORMATION

NOTE: Choose either F1 OR F2 method to calculate isopleths (not required to fill in sage boxes for both) NOTE: LDEO modeling relies on Method F2

F2: ALTERNATIVE METHOD† TO CALCULATE PK and SEL_{cum} (SINGLE STRIKE/SHOT/PULSE EQUIVALENT)

SEL_{cum}

Source Velocity (meters/second)	2.16067	4.2 knots
1/Repetition rate^ (seconds)	17.35573	37.5 m/2.16067

†Methodology assumes propagation of 20 log R; Activity duration (time) independent

^Time between onset of successive pulses.

Modified farfield SEL	**232.9819**	**232.8352**	**233.0978**	**232.8352**	**232.079**	**231.9945**
Source Factor	**1.14485E+22**	**1.10682E+22**	**1.17581E+22**	**1.10682E+22**	**9.29945E+21**	**9.12026E+21**

RESULTANT ISOPLETHS* *Impulsive sounds have dual metric thresholds (SELcum & PK). Metric producing largest isopleth should be used.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles
SEL_{cum} Threshold	183	185	155	185	203	204
PTS SEL_{cum} Isopleth to threshold (meters)	**426.9**	**0.0**	**1.3**	**13.9**	**0.0**	**20.5**

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles	
a	1	1.6	1.8	1	2	1.4	
b	2	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	0.077	
f_2	19	110	140	30	25	0.44	
C	0.13	1.2	1.36	0.75	0.64	2.35	
Adjustment (dB)†	-12.91	-56.70	-66.07	-25.65	-32.62	-4.11	OVERIDE Using LDEO Modeling

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of 20*$\log_{10}$ (Radial distance) and the modified farfield signature. For MF and HF cetaceans, pinnipeds, and sea turtles, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-5).

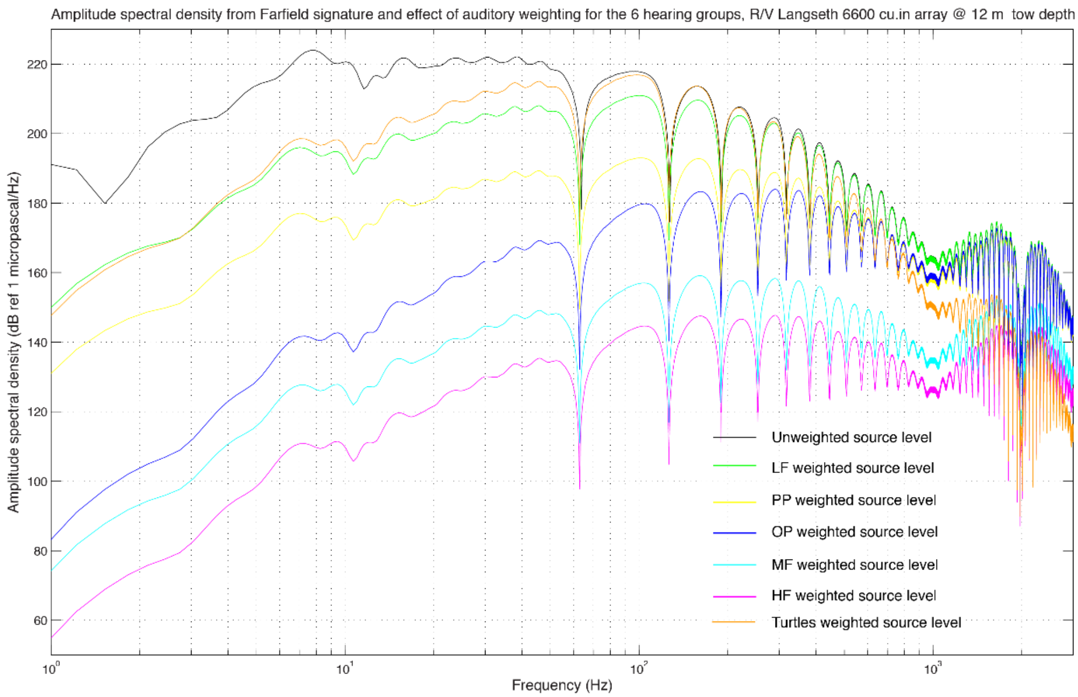

FIGURE A-5. Modeled amplitude spectral density of the 36-airgun array farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), Otariid Pinnipeds (OP), and Sea Turtles. Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.

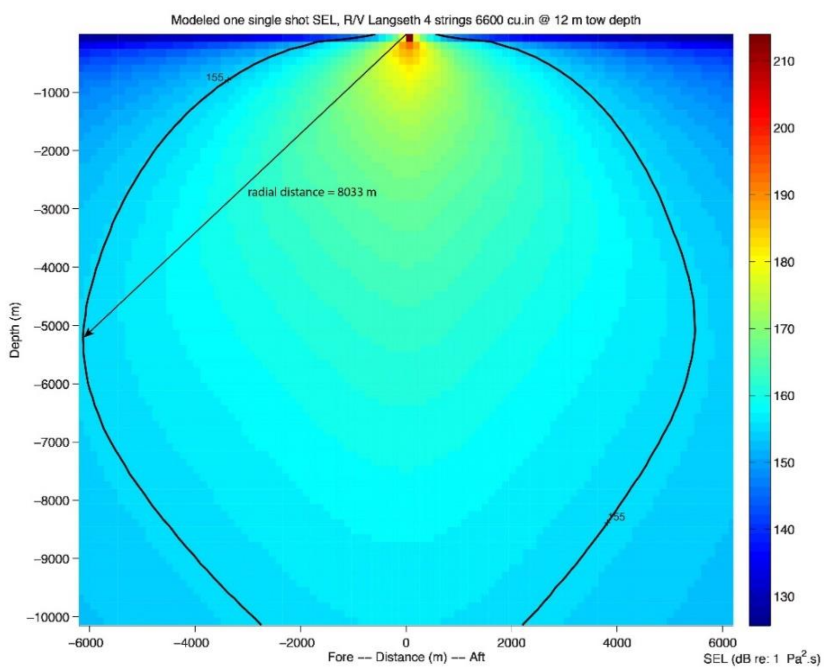

FIGURE A-6. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 155-dB SEL isopleth (8033 m). Radial distance allows us to determine the modified farfield SEL using a propagation of $20\log_{10}$(radial distance).

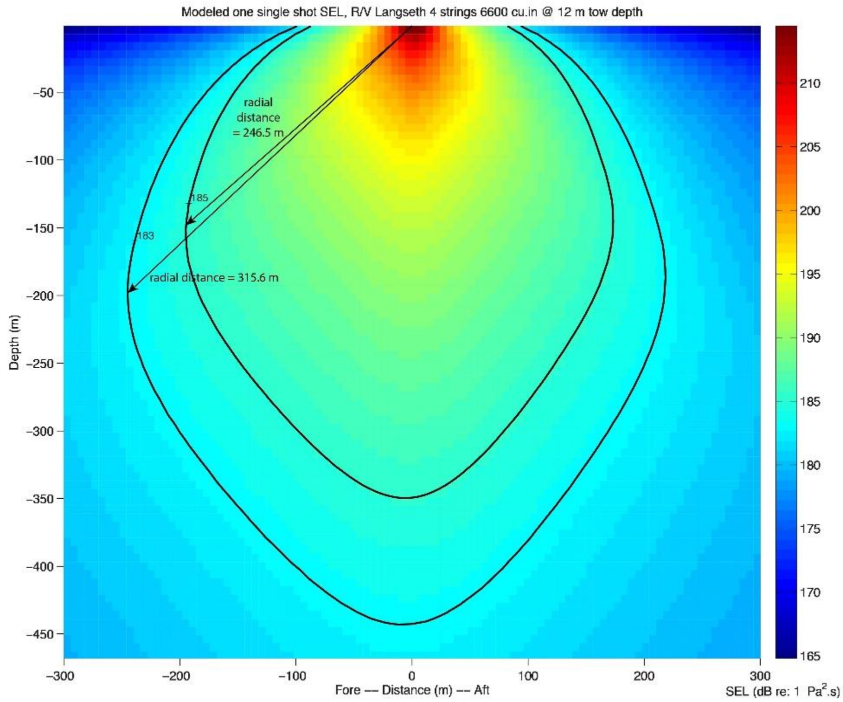

FIGURE A-7. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 183–185-dB SEL isopleths (315.6 and 246.5 m, respectively).

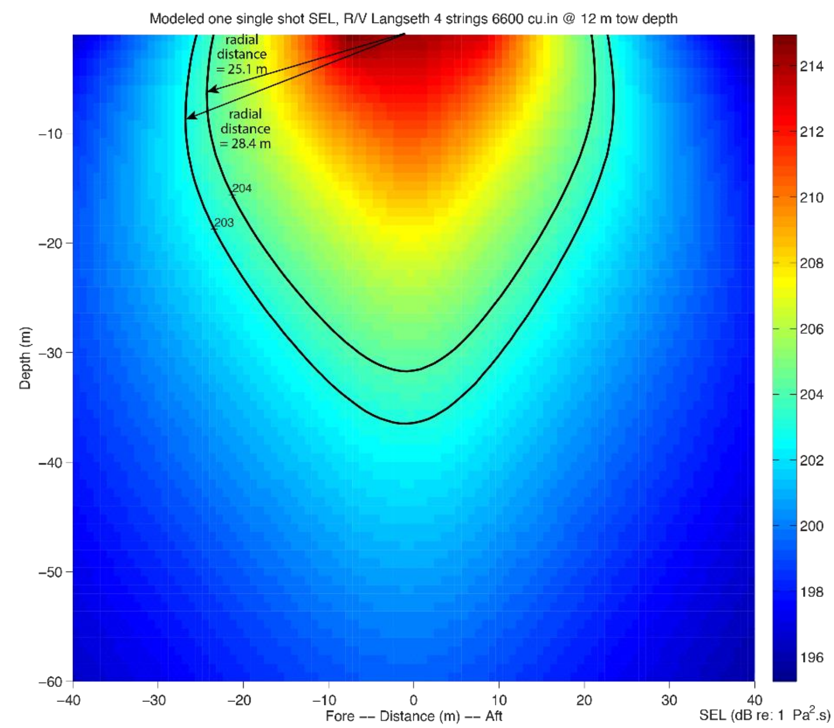

FIGURE A-8. Modeled received sound levels (SELs) in deep water from the 36-airgun array. The plot provides the radial distance from the geometrical center of the source array to the 203-dB and 204-dB SEL isopleth (28.4 m and 25.1 m, respectively).

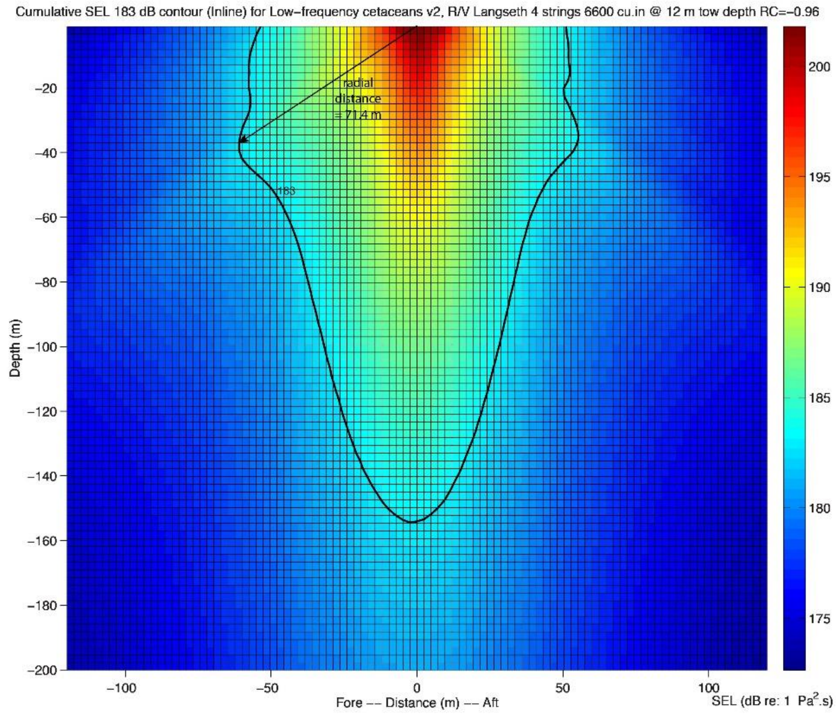

FIGURE A-9. Modeled received sound exposure levels (SELs) from the 36-airgun array at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-7 and this figure (71.4 m) allows us to estimate the adjustment in dB.

The thresholds for Peak SPL_{flat} for the 36-airgun array, as well as the distances to the PTS thresholds, are shown in Table A-4. Figures A-10–A-12 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot. A summary of the Level A threshold distances are shown in Table A-5.

For the single 40 in^3 mitigation airgun, the results for single shot SEL source level modeling are shown in Table A-6. The weighting function calculations, thresholds for SEL_{cum}, and the distances to the PTS thresholds for the 40 in^3 airgun are shown in Table A-7. Figure A-13 shows the impact of weighting functions by hearing group for the single mitigation airgun. Figures A-14–A-15 show the modeled received sound levels for single shot SEL without applying auditory weighting functions for various hearing groups. Figure A-16 shows the modeled received sound levels for single shot SEL with weighting for LF cetaceans. The thresholds for Peak SPL_{flat} for the 40 in^3 airgun, as well as the distances to the PTS thresholds, are shown in Table A-8. Figures A-17–A-18 show the modeled received sound levels to the Peak SPL_{flat} thresholds, for a single shot.

TABLE A-4. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the 36-airgun array during the proposed surveys in the Northeast Pacific Ocean.

Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
Peak Threshold	**219**	**230**	**202**	**218**	**232**
Radial Distance to Threshold (m)	45.00	13.57	364.67	51.59	10.62
Modified Farfield Peak SPL	252.06	252.65	253.24	252.25	252.52
PTS Peak Isopleth (Radius) to Threshold (m)	38.9	13.6	268.3	43.7	10.6

N.A. means not applicable or not available.

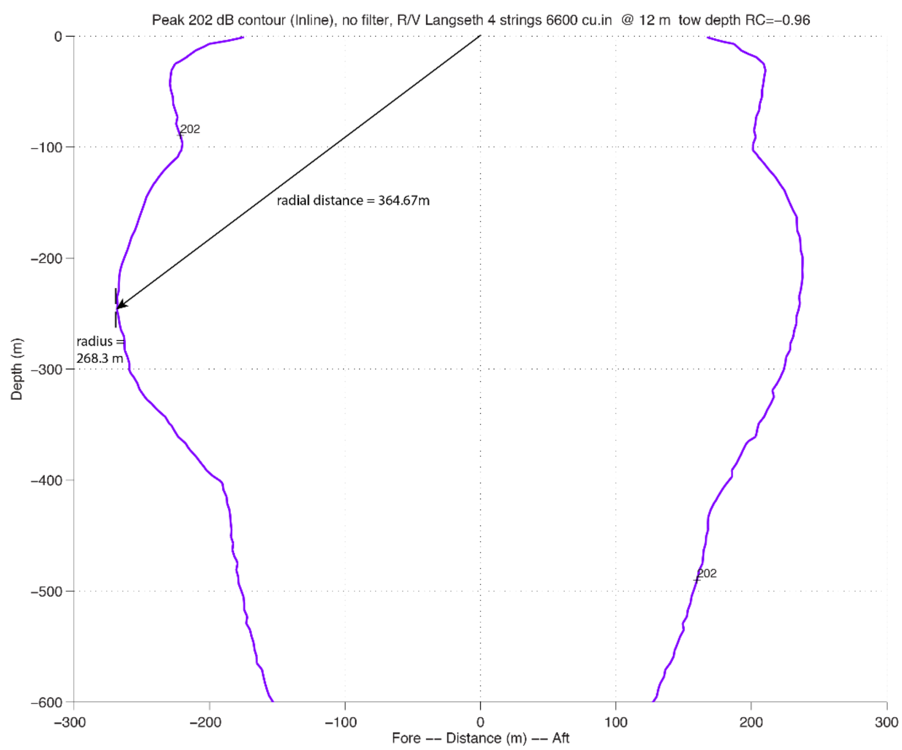

FIGURE A-10. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distance to the 202-dB Peak isopleth.

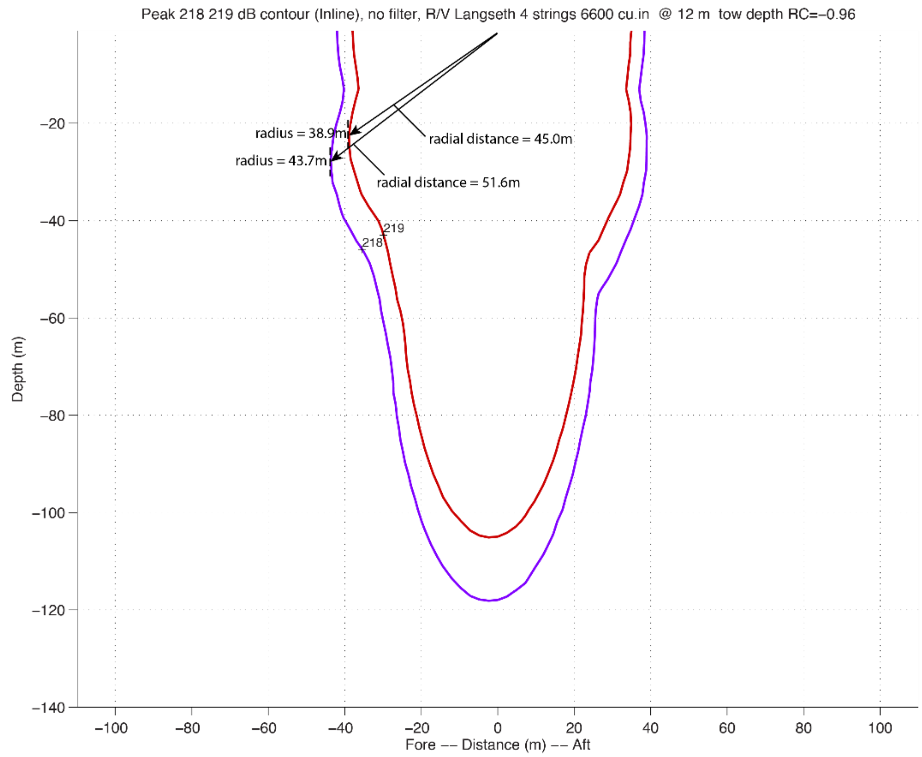

FIGURE A-11. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 218- and 219-dB Peak isopleths.

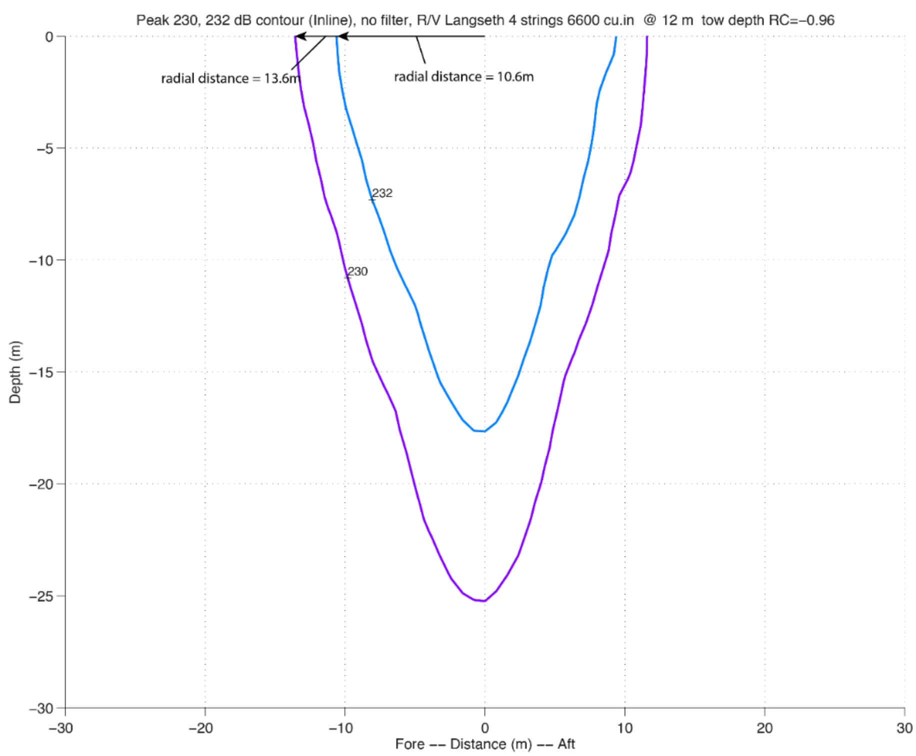

FIGURE A-12. Modeled deep-water received Peak SPL from the 36-airgun array at a 12-m tow depth. The plot provides the distances to the 230- and 232-dB Peak isopleths.

TABLE A-5. Level A threshold distances for different marine mammal hearing groups and sea turtles for the 36-airgun array. As required by NMFS (2016, 2018), the largest distance (in bold) of the dual criteria (SEL_{cum} or Peak SPL_{flat}) was used to calculate Level A takes and threshold distances.

	Level A Threshold Distances (m) for Various Hearing Groups					
	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	Sea Turtles
PTS SEL_{cum}	**426.9**	0	1.3	13.9	0	**20.5**
PTS Peak	38.9	**13.6**	**268.3**	**43.7**	**10.6**	10.6

TABLE A-6. Results for single shot SEL source level modeling for the 40 in^3 airgun with and without applying weighting function to the various hearing groups. The modified farfield signature is estimated using the distance from the source array geometrical center to where the SEL_{cum} threshold is the largest. A propagation of 20 $\log_{10}$ (Radial distance) is used to estimate the modified farfield SEL.

SEL_{cum} Threshold	**183**	**185**	**155**	**185**	**203**
Distance (m) (no weighting function)	9.9893	7.8477	294.0371	7.8477	0.9278
Modified Farfield SEL*	202.9907	202.8948	204.3680	202.8948	202.3491
Distance (m) (with weighting function)	2.3852	N.A.	N.A.	N.A.	N.A.
Adjustment (dB)	-12.44	N.A.	N.A.	N.A.	N.A.

*Propagation of 20 log R. N.A. means not applicable or not available.

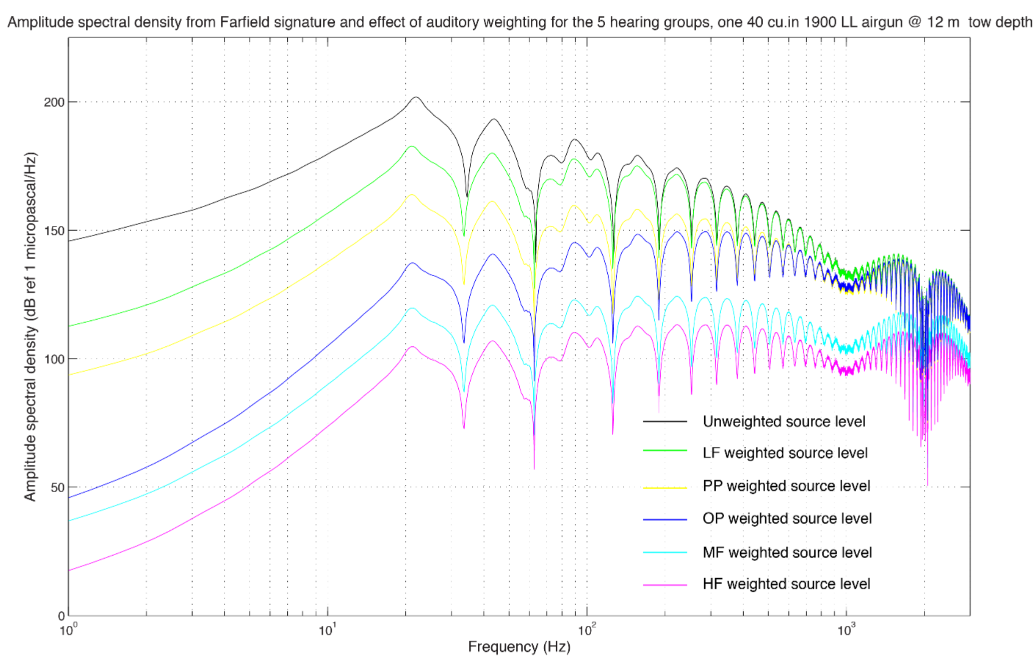

FIGURE A-13. Modeled amplitude spectral density of the 40-in^3 airgun farfield signature. Amplitude spectral density before (black) and after (colors) applying the auditory weighting functions for LF, MF, and HF cetaceans, Phocid Pinnipeds (PP), and Otariid Pinnipeds (OP). Modeled spectral levels are used to calculate the difference between the unweighted and weighted source level at each frequency and to derive the adjustment factors for the hearing groups as inputs into the NMFS User Spreadsheet.

TABLE A-7. Results for single shot SEL source level modeling for the single 40-in^3 mitigation airgun with weighting function calculations for the SEL_{cum} criteria, as well as resulting isopleths to thresholds for various marine mammal hearing groups.

STEP 1: GENERAL PROJECT INFORMATION		
PROJECT TITLE	R/V Langseth mitigation gun	
PROJECT/SOURCE INFORMATION Please include any assumptions	one 40 cu.in 1900LL airgun @ a 12 m tow depth	
PROJECT CONTACT		
STEP 2: WEIGHTING FACTOR ADJUSTMENT		Specify if relying on source-specific WFA, alternative weighting/dB adjustment, or if using default value
Weighting Factor Adjustment (kHz)[¥]	NA	Override WFA: Using LDEO modeling
[¥] Broadband: 95% frequency contour percentile (kHz) OR Narrowband: frequency (kHz); For appropriate default WFA: See INTRODUCTION tab		
		† If a user relies on alternative weighting/dB adjustment rather than relying upon the WFA (source-specific or default), they may override the Adjustment (dB) (row 62), and enter the new value directly. However, they must provide additional support and documentation supporting this modification.

STEP 3: SOURCE-SPECIFIC INFORMATION

NOTE: Choose either F1 OR F2 method to calculate isopleths (not required to fill in sage boxes for both) — NOTE: LDEO modeling relies on Method F2

F2: ALTERNATIVE METHOD† TO CALCULATE PK and SEL_{cum} (SINGLE STRIKE/SHOT/PULSE EQUIVALENT)

SEL_{cum}

Source Velocity (meters/second)	2.16067	4.2 knots
1/Repetition rate^ (seconds)	17.35572762	37.5/2.16067

†Methodology assumes propagation of 20 log R; Activity duration (time) independent

^Time between onset of successive pulses.

	Modified farfield SEL	202.9907	202.8948	204.368	202.8948	202.3491
	Source Factor	1.14717E+19	1.12211E+19	1.57528E+19	1.12211E+19	9.89617E+18
RESULTANT ISOPLETHS*	*Impulsive sounds have dual metric thresholds (SELcum & PK). Metric producing largest isopleth should be used.					
	Hearing Group	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds
	SEL_{cum} Threshold	183	185	155	185	203
	PTS SEL_{cum} Isopleth to threshold (meters)	0.5	0	0	0	0

WEIGHTING FUNCTION CALCULATIONS

Weighting Function Parameters	Low-Frequency Cetaceans	Mid-Frequency Cetaceans	High-Frequency Cetaceans	Phocid Pinnipeds	Otariid Pinnipeds	
a	1	1.6	1.8	1	2	
b	2	2	2	2	2	
f_1	0.2	8.8	12	1.9	0.94	
f_2	19	110	140	30	25	
C	0.13	1.2	1.36	0.75	0.64	
Adjustment (dB)†	-12.44	-60.85	-70.00	-30.09	-36.69	OVERIDE Using LDEO Modeling

†For LF cetaceans, the adjustment factor (dB) is derived by estimating the radial distance of the 183-dB isopleth without applying the weighting function and a second time with applying the weighting function. Adjustment was derived using a propagation of 20*$\log_{10}$ (Radial distance) and the modified farfield signature. For MF and HF cetaceans and pinnipeds, the difference between weighted–unweighted spectral source levels at each frequency was integrated to calculate adjustment factors (see spectrum levels in Figure A-13).

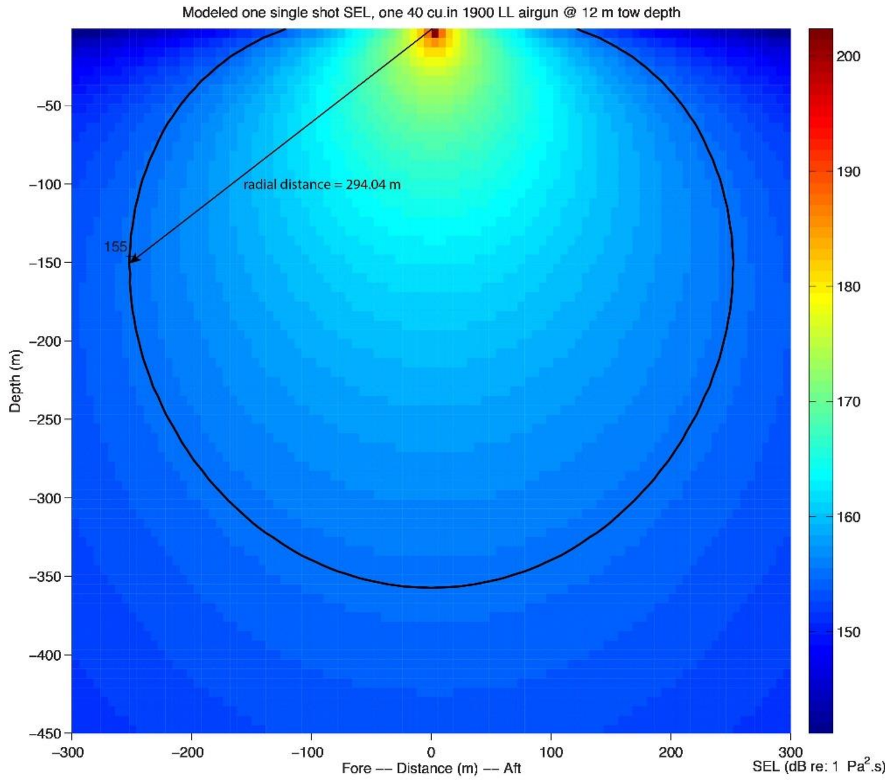

FIGURE A-14. Modeled received sound levels (SELs) in deep water from one 40-in³ airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 155-dB SEL isopleth (294.04 m).

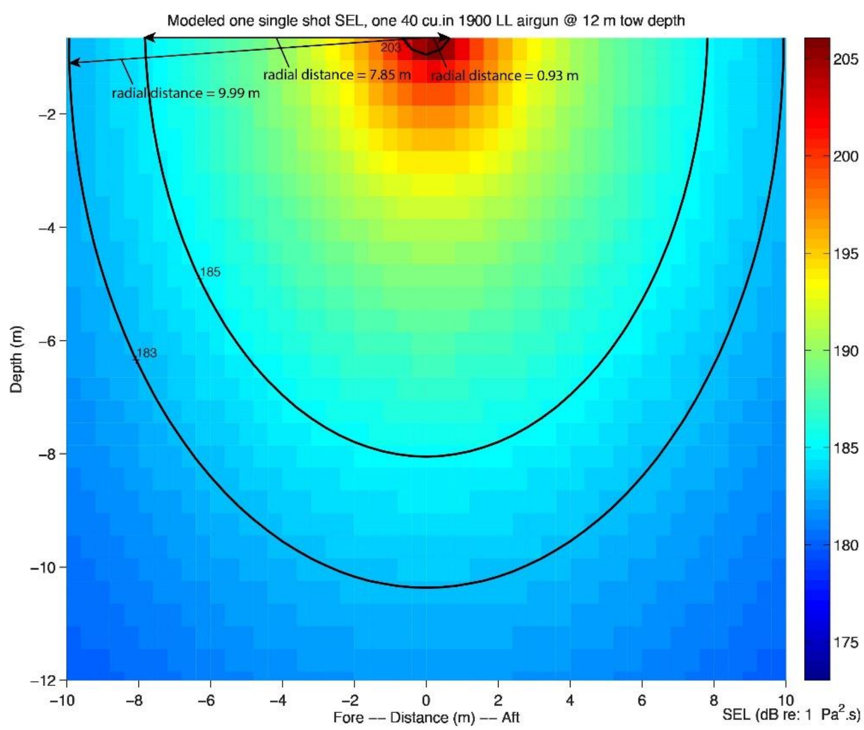

FIGURE A-15. Modeled received sound levels (SELs) in deep water from one 40-in³ airgun at a 12-m tow depth. The plot provides the distance from the geometrical center of the source array to the 183–185 dB and 203 dB SEL isopleths.

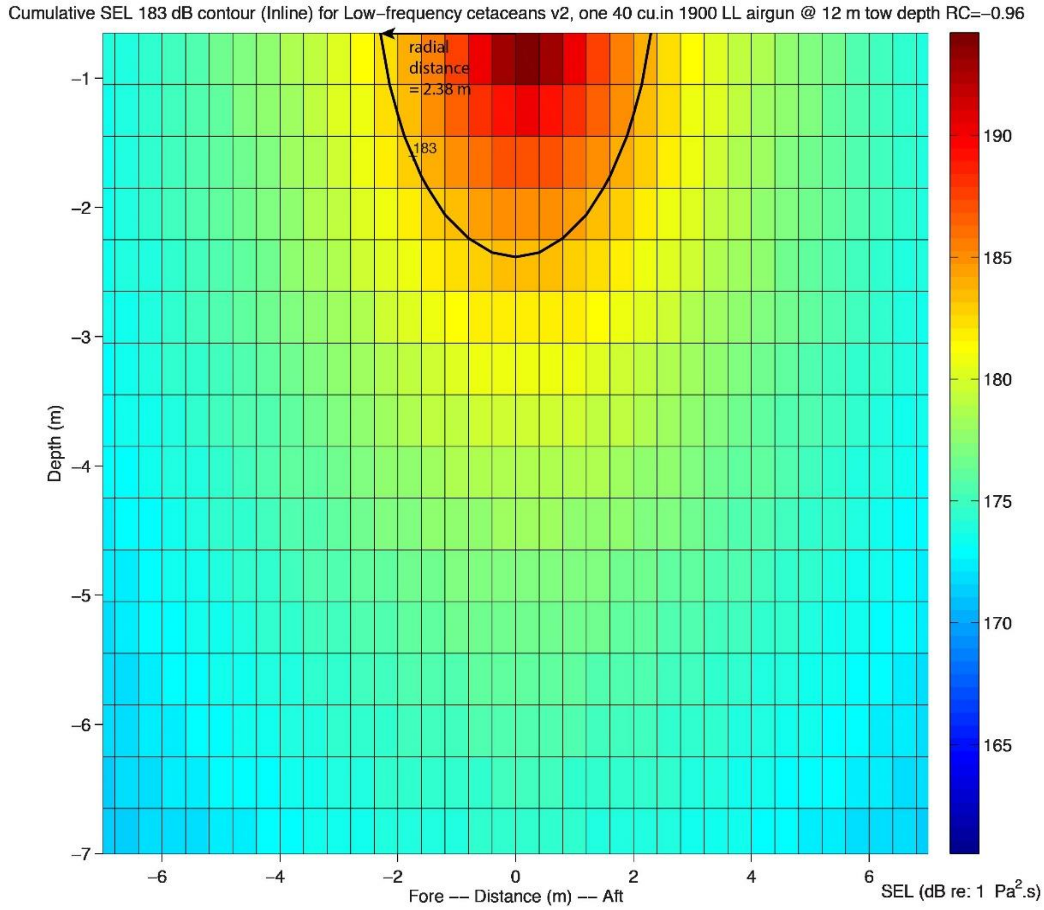

FIGURE A-16. Modeled received sound exposure levels (SELs) from one 40-in^3 mitigation at a 12-m tow depth, after applying the auditory weighting function for the LF cetaceans hearing group following the NMFS Technical Guidance. The plot provides the radial distance to the 183-dB SEL_{cum} isopleth for one shot. The difference in radial distances between Fig. A-15 and this figure allows us to estimate the adjustment in dB.

TABLE A-8. NMFS Level A acoustic thresholds (Peak SPL_{flat}) for impulsive sources for marine mammals and predicted distances to Level A thresholds for various marine mammal hearing groups that could be received from the 40-in^3 airgun during the proposed seismic surveys in the Northeast Pacific Ocean.

Hearing Group	**Low-Frequency Cetaceans**	**Mid-Frequency Cetaceans**	**High-Frequency Cetaceans**	**Phocid Pinnipeds**	**Otariid Pinnipeds**
Peak Threshold	**219**	**230**	**202**	**218**	**232**
PTS Peak Isopleth (Radius) to Threshold (m)	1.76	0.51	12.5	1.98	0.40

N.A. means not applicable or not available.

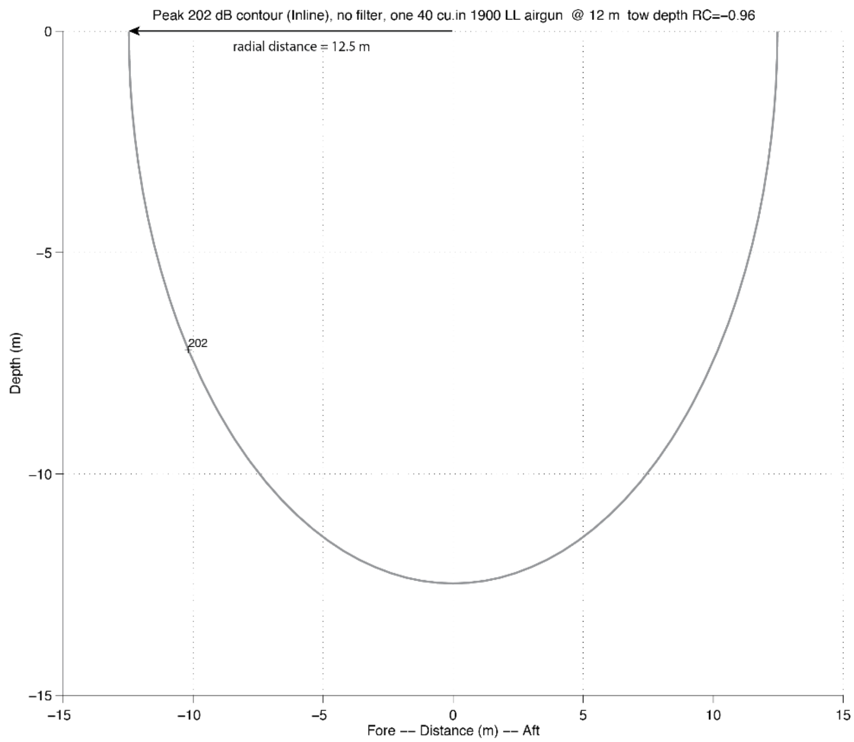

FIGURE A-17. Modeled deep-water received Peak SPL from one 40 in^3 airgun at a 12-m tow depth. The plot provides the radial distance from the source geometrical center to the 202-dB Peak isopleth.

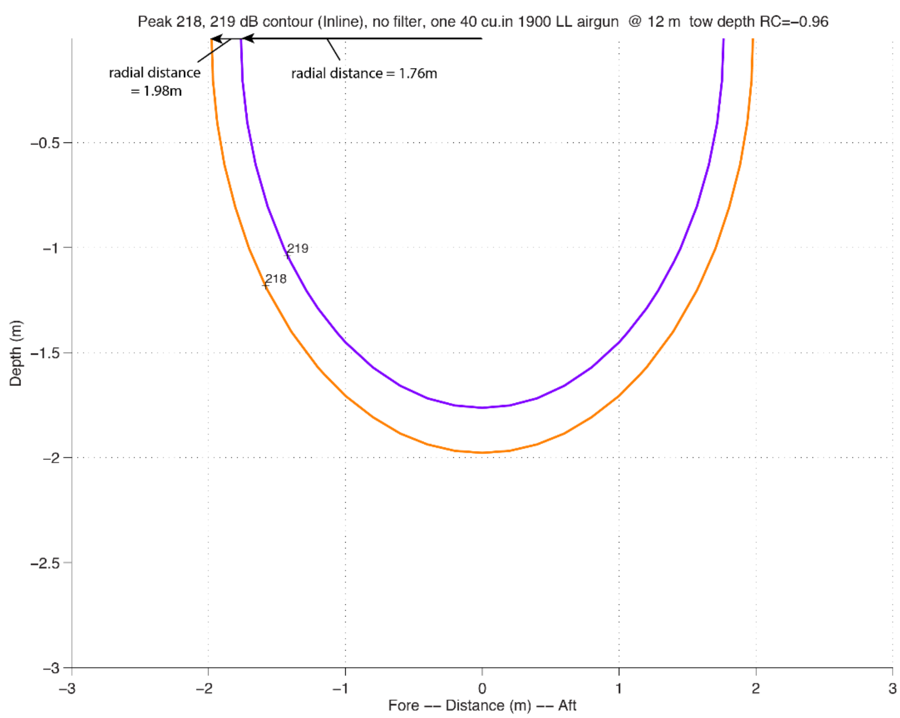

FIGURE A-18. Modeled deep-water received Peak SPL from one 40 in^3 airgun at a 12-m tow depth. The plot provides the radial distances from the source geometrical center to the 218 and 219-dB Peak isopleths.

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ADDENDUM

Using Empirical Data for Estimation of Level B Radii

Based on Crone et al. (2014; *Estimating shallow water sound power levels and mitigation radii for the R/V Marcus G. Langseth using an 8 km long MCS streamer*), empirical data collected on the Cascadia Margin in 2012 during the COAST Survey support the use of the multichannel seismic (MCS) streamer data and the use of Sound Exposure Level (SEL) as the appropriate measure to use for the prediction of mitigation radii for the proposed survey. In addition, this peer-reviewed paper showed that the method developed for this purpose is most appropriate for shallow water depths, up to ~200 m deep.

To estimate Level B (behavioral disturbance or harassment) radii in shallow and intermediate water depths, we used the received levels from MCS data collected by R/V *Langseth* during the COAST survey (Crone et al. 2014). Streamer data in shallow water collected in 2012 have the advantage of including the effects of local and complex subsurface geology, seafloor topography, and water column properties and thus allow us to establish mitigation radii more confidently than by using the data from calibration experiments in the Gulf of Mexico (Tolstoy et al. 2004, 2009; Diebold et al. 2010).

As shown by Madsen et al. (2005), Southall et al. (2007), and Crone et al. (2014), the use of the root mean square (RMS) pressure levels to calculate received levels of an impulsive source leads to undesirable variability in levels due to the effects of signal length, potentially without significant changes in exposure level. All these studies recommend the use of SEL to establish impulsive source thresholds used for mitigation. Here we provide both the actual measured 160 dB_{RMS} and 160 dB_{SEL} to demonstrate that for determining mitigation radii in shallow water and intermediate, both would be significantly less than the modeled data for this region.

The proposed surveys would acquire data with a 4 string 6600 in^3 airgun array at a tow depth of 12 m, while the data collected in 2012 were acquired with a 4 string 6600 in^3 airgun array at a tow depth of 9 m. To account for the differences in tow depth between the COAST survey (6600 in^3 at 9 m tow depth) and the proposed survey (6600 in^3 at 12 m tow depth), we calculated a scaling factor using the deepwater modeling. The 150 dB_{SEL} corresponds to deep-water maximum radii of 10,533 m for the 6600 in^3 airguns at 12 m tow depth, and 9,149 m for the 6600 in^3 at a 9 m tow depth yielding a scaling factor of 1.15 to be applied to the shallow-water and intermediate-water 9 m tow depth results.

As the 6600 cu.in source is 18 m wide (across-line direction) and 16m long (along-line direction), this quasi-symmetric source is also able to capture azimuthal variations.

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Extracted from Crone et al. 2014 – Section 4.1

4. Discussion

4.1. RMS Versus SEL In his paper, Madsen [2005] makes a compelling argument against the use of RMS (equation (3)) for the determination of safe exposure levels and mitigation radii for marine protected species, partially on the grounds that this measure does not take into account the total acoustic energy that an animal's auditory system would experience. Madsen [2005] recommended the use of SEL as well as measures of peak pressure to establish impulsive source thresholds used for mitigation. Southall et al. [2007] came to similar conclusions.

Our work should provide further motivation for a regulatory move away from RMS power levels for marine protected species mitigation purposes. In shallow waters especially, interactions between direct, reflected, and refracted arrivals of acoustic energy from the array can result in large variations in signal length (T_{90}), and commensurate large variations in RMS without necessarily significant changes in exposure level. The use of SEL, which accounts for signal length, should be preferred for mitigation purposes in shallow water.

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The entire 16 0dB$_{SEL}$ level data are within the length of the streamer and are well behaved throughout this depth profile. The measured sound level data in this area suggest that the 160d B$_{SEL}$ mitigation radius distance would be well defined at a maximum of 8192 m, but that the 160 dB$_{RMS}$ would be close to ~11 km (Fig. 1). For a few shots along this profile, the 160 dB$_{RMS}$ is just beyond the end of the streamer (8 km). For these shots, extrapolation was necessary. Crone et al. (2014) could only extrapolate the 160 dB$_{RMS}$ levels up to a distance of ~11 km (~133% of the length of the streamer). However, the stable 160 dB$_{SEL}$ levels across this interval would support an extrapolated value of not much more than 11 km for the 160 dB$_{RMS}$ level given that the 160 dB$_{RMS}$ and 160 dB$_{SEL}$ levels track consistently along the profile (Fig. 1).

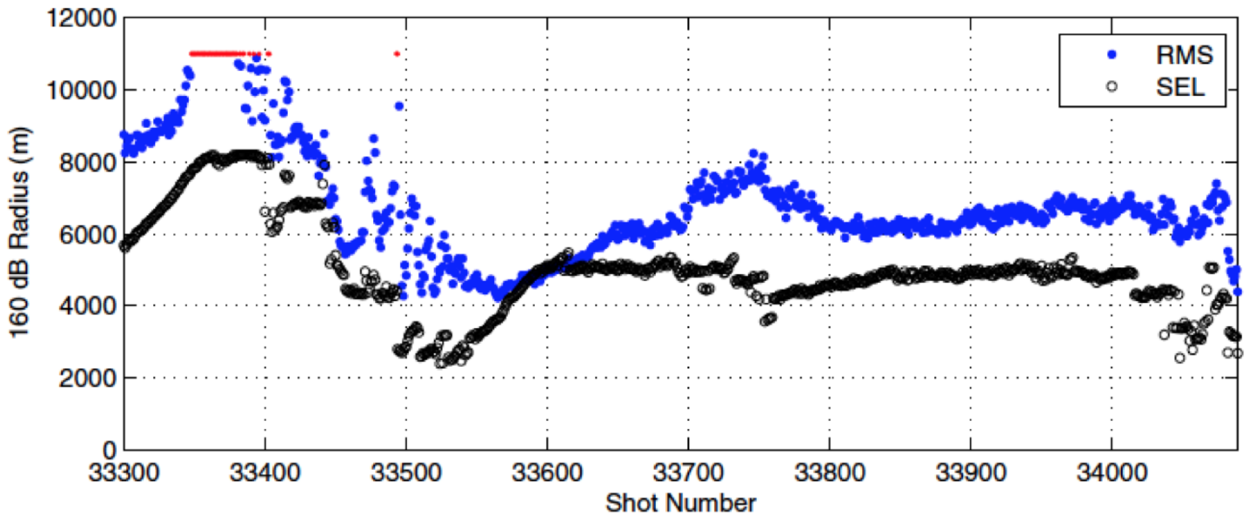

FIGURE 1. Measured radius distances to the 160 dB radii for both SEL and RMS along line A/T collected in 2012 at Cascadia with R/V *Langseth* 6600 in^3 airgun array towed at a depth of 9 m (Fig. 12 from Crone et al. 2014). This line extends across the shelf from ~50m water depth (Shot 33,300), 100m water depth (Shot # 33,675) out ~to the shelf break at 200m water depth (~Shot # 34000).

As noted in Table 2 of Crone et al. (2014), the full range of 160 dB$_{RMS}$ measured radii for intermediate waters is 4291m to 8233 m. The maximum 160 dB$_{RMS}$ measured radii, 8233 m (represented by a single shot at ~33750 from Figure 1), was selected for the 160 dB$_{RMS}$ measured radii in Table 1. Only 2 shots in water depths >100 have radii that exceed 8000 m, and there were over 1100 individual shots analyzed in the data; thus, the use of 8233 m is conservative.

Summary

The empirical data collected during the COAST Survey on Cascadia Margin and measured 160 dB$_{RMS}$ and 160 dB$_{SEL}$ values demonstrate that the modeled predictions are quite conservative by a factor of up to ~2 to 2.5 times less than modeled predictions for the 2020 Cascadia project. While we have sought to err on the conservative side for our activities, being overly conservative can dramatically overestimate potential and perceived impacts of a given activity. We understand that the 160 dB$_{RMS}$ is the current threshold, and have highlighted that here as the standard metric to be used. However, evidence from multiple publications including Crone et al. (2014) have argued that SEL is a more appropriate metric for mitigation radii calculations. However, it is important to note that use of either measured SEL or RMS metrics yields significantly smaller radii in shallow water than model predictions.

TABLE 1. Comparison of modeled mitigation radii with empirically-derived radii from the Cascadia Margin during the 2012 COAST survey for the 4-string 36 airgun array (6600 in^3).

Water Depth (m)	Proposed Project Radii using L-DEO Modeling	COAST project Radii using L-DEO Modeling	Predicted Radii for Proposed Project using Empirical Data (Crone et al. 2014). 160 dB rms measured distance proposed for current project shown in red.			
	Distance (m) to 160-dB$_{rms}$ at 12 m tow depth	Distance (m) to 160-dB$_{rms}$ at 9 m tow depth	Distance (m) to 160-dB$_{SEL}$ at 9 m tow depth (Figure 12 *in* Crone et al. 2014)	Distance (m) to 160-dB$_{SEL}$ with conversion factor (1.15) from 9 to 12 m tow depth	Distance (m) to 160 dB$_{rms}$ at 9 m tow depth (Figure 12 *in* Crone et al. 2014)	Distance (m) to 160 dB$_{rms}$ with conversion factor (1.15) from 9 to 12 m tow depth
<100	25,494	20,550	8,192	9,421	11,000*	12,650
100-1000	10,100	12,200	5,487	6,300	8,233	9,468

*This value is extrapolated from end of 8-km streamer. Based on stable SEL values at same shot values. RMS extrapolated value is reasonable approximation.

When evaluating the empirical and modeled distances, all the other considerations and aspects of the airgun array still apply including:

- the airgun array is actually a distributed source and the predicted farfield level is never actually fully achieved
- the downward directionality of the airguns means that the majority of energy is directed downwards and not horizontally
- animals observed at the surface benefit from Lloyds mirror effect
- there is only one source vessel and the entire survey area is not ensonified all at one time, but rather the much smaller area around the vessel.

For these reasons, we believe the more scientifically appropriate approach for the proposed survey is to use Level B threshold distances based on the empirical data for shallow and intermediate water depths.

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APPENDIX B: METHODS FOR MARINE MAMMAL DENSITIES, ENSONIFIED AREAS, AND TAKE CALCULATIONS

APPENDIX B: MARINE MAMMAL DENSITIES, ENSONIFIED AREAS, AND TAKE CALCULATIONS

The U.S. Navy primarily used SWFSC spatial models to develop a marine species density database for the Northwest Training and Testing Study Area (USN 2019), which encompasses the U.S. portion of the proposed survey area; if no density spatial modeling was available, other data sources were used (USN 2019a). The USN marine species density database is currently the most comprehensive density data set available for the CCE. However, GIS data layers are currently unavailable for the database; thus, in this analysis the USN data were used only for species for which density data were not available from an alternative spatially-explicit model (e.g., minke, sei, gray, false killer, killer, and short-finned pilot whales, *Kogia* spp., pinnipeds, and leatherback sea turtle). For these species, GIS was used to determine the areas expected to be ensonified in each density category. The densities (Table B-1) were then multiplied by the ensonified areas (Table B-2) to determine Level A and Level B takes (Tables B-3 and B-4).

As recommended by NMFS, spatially-explicit density data from the NOAA CetSound website (NOAA 2019k) were used for most other species (i.e., humpback, blue, fin, sperm, Baird's beaked, and other small beaked whales; bottlenose, striped, short-beaked common, Pacific white-sided, Risso's, and northern right whale dolphins; and Dall's porpoise). CetMap (https://cetsound.noaa.gov/cda) provides output habitat-based density models for cetaceans in the CCE. As CetMap provides output from habitat-based density models for cetaceans in the CCE (Becker et al. 2016) in the form of GIS layers; these were used to calculate takes in the survey area. The density estimates were available in the form of a GIS grid with each cell in the grid measuring ~7 km east-west by 10 km north-south. This grid was intersected with a GIS layer of the areas expected to be ensonified to >160 dB SPL within the three water depth categories (<100 m, 100–1000 m, >1000 m). The densities from all grid cells overlapping the ensonified areas within each water depth category were averaged to calculate a zone-specific density for each species (Table B-1). These densities were then multiplied by the total area (for the U.S. and non-territorial waters of Canada) within each water depth category expected to be ensonified above the relevant threshold levels to estimate Level A and Level B takes (Tables B-3 and B-4). As CetMap did not have a spatially-explicit GIS density layer for the harbor porpoise, densities from Forney et al. (2014) were used for that species for the portions of the survey area that occurred within the 200-m isobath (Table B-1).

The requested take for false killer whales was increased to mean group size provided by Mobley et al. (2000), as no density information was available for Oregon, Washington, or B.C. The requested takes for small beaked whales were assigned to various species as follows: assuming that Cuvier's beaked whale and Stejneger's beaked whale are expected to occur in similar numbers in the survey area as Baird's beaked whale, the same take as determined for Baird's beaked whale was assigned to the other two beaked whale species (i.e., 86 individuals each). As Blainville's beaked whale is unlikely to occur in the survey area, it was allotted a take of 7 individuals or the maximum group size as reported by Jefferson et al. (2015). The remaining takes (71) were assigned to Hubbs' beaked whale, which is expected to be rare in the survey area.

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TABLE B-1. Marine mammal densities expected to occur in the proposed survey area in the Northeast Pacific Ocean.

		Estimated Density (#/km^2)					
Species	Category	Density (not by water depth)	Shallow water <100 m	Intermediate water 100-1000 m	Deep water >1000 m	Source	Comments
LF Cetaceans							
North Pacific right whale			*0*	*0*	*0*		Not provided but near zero
Humpback whale			*0.005240*	*0.004020*	*0.000483*	Becker et al. (2016)	Summer/fall
Blue whale			0.002023	0.001052	0.000358	Becker et al. (2016)	Annual densities
Fin whale			*0.000202*	*0.000931*	*0.001381*	Becker et al. (2016)	Annual densities
Sei whale			*0.000400*	*0.000400*	*0.000400*	USN (2019a)	Annual densities
Minke whale			*0.001300*	*0.001300*	*0.001300*	USN (2019a)	Annual densities
Gray whale							
	1: 0-10 km from shore	0.015500				USN (2019a)	Density for summer (July-November)
	2: 10-47 km from shore	0.001000				USN (2019a)	Density for summer (July-November)
MF Cetaceans							
Sperm whale			*0.000059*	*0.000156*	*0.001302*	Becker et al. (2016)	Annual densities
Baird's beaked whale			0.000114	0.000300	0.001468	Becker et al. (2016)	Annual densities
Small beaked whale			0.000788	0.001356	0.003952	Becker et al. (2016)	Annual densities
Bottlenose dolphin			0.000001	0.000001	0.000011	Becker et al. (2016)	Annual densities
Striped dolphin			0.000000	0.000002	0.000133	Becker et al. (2016)	Annual densities
Short-beaked common dolphin			0.000508	0.001029	0.001644	Becker et al. (2016)	Annual densities
Pacific white-sided dolphin			0.051523	0.094836	0.070060	Becker et al. (2016)	Annual densities
Northern right-whale dolphin			0.010178	0.043535	0.062124	Becker et al. (2016)	Annual densities
Risso's dolphin			0.030614	0.030843	0.015885	Becker et al. (2016)	Annual densities
False killer whale			N.A.	N.A.	N.A.		
Killer whale (Offshore waters)			0.000920	0.000920	0.000920	USN (2019b)	Annual densities
Short-finned pilot whale			0.000250	0.000250	0.000250	USN (2019a)	Annual densities
HF Cetaceans							
Pygmy/dwarf sperm whale			0.001630	0.001630	0.001630	USN (2019a)	Annual densities
Dall's porpoise			0.145077	0.161061	0.113183	Becker et al. (2016)	Summer/fall
Harbor porpoise							
	1: North of 45N	0.624000				Forney et al. (2014)	Annual density north of 45N, within 200-m isobath
	2: South of 45N	0.467000				Forney et al. (2014)	Annual density south of 45N, within 200-m isobath
Otariid Seals							
Northern fur seal*							
	1: up to 70 km from shore	0.010912				USN (2019a)	Density for July
	2: 70-130 km from shore	0.129734				USN (2019a)	Density for July
	3: >130 km from shore	0.009965				USN (2019a)	Density for July
*Guadalupe fur seal**							
	1: within 200-m isobath	*0.023477*				USN (2019a)	Density for summer (other densities lower)
	2: 200-m isobath to 300 km	*0.026260*				USN (2019a)	Density for summer (other densities lower)
California sea lion							
	1: 0-40 km from shore	0.028800				USN (2019a)	Density for August (density zero during June and July)
	2: 40-70 km from shore	0.003700				USN (2019a)	Density for August (density zero during June and July)
	3: 70-450 km from shore	0.006500				USN (2019a)	Density for August (density zero during June and July)
Steller sea lion*							
	1: within 200-m isobath	0.480489				USN (2019a)	Average densities for OR/WA for summer
	2: 200-m isobath to 300 km	0.003581				USN (2019a)	Average densities for OR/WA for summer
Phocid Seals							
Northern elephant seal*			0.034600	0.034600	0.034600	USN (2019a)	Density for summer
Harbor seal							
	1: within 30 km from shore	0.342400				USN (2019a)	Annual density within 30 km from WA/OR shore
Turtle							
Leatherback Turtle			0.000114	0.000114	0.000114	USN (2019a)	Annual density

*Densities adjusted for most recent population size.
N.A. is not applicable.

TABLE B-2. Areas expected to ensonified during the proposed survey in the Northeast Pacific Ocean.

Survey Zone		Criteria	Daily Ensonified Area (km^2)	Total Survey Days	Total Ensonified Area (km^2)	Relevant Isopleth (m)
Shallow <100 m		160 dB	96.8	37	3,580.7	12650
Intermediate 100-1000 m		160 dB	636.8	37	23,562.4	9468
Deep >1000 m		160 dB	1417.3	37	52,438.7	6733
	Overall	**Level B**	**2150.9**	**37**	**79,581.9**	
		Level A				
All zones		LF Cetacean	144.2	37	5,334.5	426.9
All zones		MF Cetacean	4.6	37	171.4	13.6
All zones		HF Cetacean	90.9	37	3,364.0	268.3
All zones		Otariid	3.6	37	133.6	10.6
All zones		Phocid	14.9	37	550.5	43.7
All zones		Sea Turtle	7.0	37	258.3	20.5

TABLE B-3. Take estimates for the proposed survey area in the Northeast Pacific Ocean for the harbor porpoise and species with densities from USN (2019a,b).

	Estimated Density (#/km²)				Level B 160 dB Ensonified Area (km²)			Level A Ensonified Area (km²)			Level B Takes							
Species	Shallow <100 m / Category 1	Intermediate 100-1000 m / Category 2	Deep >1000 m / Category 3	Regional Population Size	Shallow <100 m / Category 1	Intermediate 100-1000 m / Category 2	Deep >1000 m / Category 3	Category 1	Category 2	Category 3	Shallow <100 m / Category 1	Intermediate 100-1000 m / Category 2	Deep >1000 m / Category 3	Level B Takes (All)	Just Level B Takes	Level A Takes	% of Pop. (Total Takes)	Requested Level A+B Take Authorization
LF Cetaceans																		
North Pacific right whale	*0*	*0*	*0*	400	3,581	23,562	52,439	5,335			0	0	0	0	0	0	0.00	0
Sei whale	*0.0004000*	*0.0004000*	*0.0004000*	27,197	3,581	23,562	52,439	5,335			1	9	21	32	30	2	0.12	32
Minke whale	0.0013000	0.0013000	0.0013000	20,000	3,581	23,562	52,439	5,335			5	31	68	103	96	7	0.52	103
Gray whale	0.0155000	0.0010000		26,960	1,433	21,376		1	1,416		22	21	0	44	43	1	0.16	44
MF Cetaceans																		
False killer whale	N.A.	N.A.	N.A.	N.A.	3,581	23,562	52,439	171			N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	**5**
Killer whale	0.0009200	0.0009200	0.0009200	918	3,581	23,562	52,439	171			3	22	48	73	73	0	7.98	73
Short-finned pilot whale	0.0002500	0.0002500	0.0002500	836	3,581	23,562	52,439	171			1	6	13	20	20	0	2.38	**29**
HF Cetaceans																		
Pygmy/dwarf sperm whale	0.0016300	0.0016300	0.0016300	4,111	3,581	23,562	52,439	3,364			6	38	85	130	125	5	3.16	130
Harbor porpoise	0.6240000	0.4670000		53,773	7,469	7,667		264	253		4,661	3,580	0	8,241	7,958	283	15.33	8,241
Otariid Seals																		
Northern fur seal	0.0109117	0.1297339	0.0099653	620,660	31,886	30,068	17,628	48	55	30	348	3,901	176	4,424	4,416	8	0.71	4,424
Guadalupe fur seal	*0.0234772*	*0.0262595*		34,187	15,136	64,446		516	113		355	1,692	0	2,048	2,033	15	5.99	2,048
California sea lion	0.0288000	0.0037000	0.0065000	257,606	18,356	13,530	47,696	28	20	86	529	50	310	889	888	1	0.35	889
Steller sea lion	0.4804893	0.0035811		77,149	15,136	64,446		516	113		7,273	231	0	7,504	7,255	249	9.73	7,504
Phocid Seal																		
Northern elephant seal	0.0345997	0.0345997	0.0345997	179,000	3,581	23,562	52,439	551			124	815	1,814	2,754	2,735	19	1.54	2,754
Harbor seal	0.3424000			129,732	11,351			63			3,887	0	0	3,887	3,865	22	3.00	3,887
Sea Turtle																		
Leatherback Turtle	0.0001140	0.0001140	0.0001140		985.5	7,810.4	16,244.5	258.3						3	3	0		3

N.A. means not available. * Requested take for the false killer whale is based on mean group size (Mobley et al. 2000). For different categories, see density table (Table B-1).

TABLE B-4. Take estimates for the proposed survey area in the Northeast Pacific Ocean for the species with densities from Becker et al. (2016).

	Estimated Density (#/km²)				Level B 160 dB Ensonified Area (km²)			Level A Ensonified Area (km²)			Level B Takes							
Species	Shallow <100 m / Category 1	Intermediate 100-1000 m / Category 2	Deep >1000 m / Category 3	Regional Population Size	Shallow <100 m / Category 1	Intermediate 100-1000 m / Category 2	Deep >1000 m / Category 3	Category 1	Category 2	Category 3	Shallow <100 m / Category 1	Intermediate 100-1000 m / Category 2	Deep >1000 m / Category 3	Level B Takes (All)	Just Level B Takes	Level A Takes	% of Pop. (Total Takes)	Requested Level A+B Take Authorization
LF Cetaceans																		
Humpback whale	*0.0052405*	*0.0040200*	*0.0004830*	10,103	3,581	23,562	52,439	5,335			19	95	25	139	111	28	1.37	139
Blue whale	*0.0020235*	*0.0010518*	*0.0003576*	1,496	3,581	23,562	52,439	5,335			7	25	19	51	40	11	3.39	51
Fin whale	*0.0002016*	*0.0009306*	*0.0013810*	18,680	3,581	23,562	52,439	5,335			1	22	72	95	94	1	0.51	95
MF Cetaceans																		
Sperm whale	*0.0000586*	*0.0001560*	*0.0013023*	26,300	3,581	23,562	52,439	171			0	4	68	72	72	0	0.27	72
Baird's beaked whale	*0.0001142*	*0.0002998*	*0.0014680*	2,697	3,581	23,562	52,439	171			0	7	77	84	84	0	3.13	84
Small beaked whale	*0.0007878*	*0.0013562*	*0.0039516*	6,318	3,581	23,562	52,439	171			3	32	207	242	242	0	3.83	242
Bottlenose dolphin	*0.0000007*	*0.0000011*	*0.0000108*	1,924	3,581	23,562	52,439	171			0	0	1	1	1	0	0.03	**13**
Striped dolphin	*0.0000000*	*0.0000025*	*0.0001332*	29,211	3,581	23,562	52,439	171			0	0	7	7	7	0	0.02	**46**
Short-beaked common dolphin	*0.0005075*	*0.0010287*	*0.0016437*	969,861	3,581	23,562	52,439	171			2	24	86	112	112	0	0.01	**179**
Pacific white-sided dolphin	*0.0515230*	*0.0948355*	*0.0700595*	48,974	3,581	23,562	52,439	171			184	2,235	3,674	6,093	6,084	9	12.44	6,093
Northern right-whale dolphin	*0.0101779*	*0.0435350*	*0.0621242*	26,556	3,581	23,562	52,439	171			36	1,026	3,258	4,320	4,318	2	16.27	4,320
Risso's dolphin	*0.0306137*	*0.0308426*	*0.0158850*	6,336	3,581	23,562	52,439	171			110	727	833	1,669	1,664	5	26.35	1,669
HF Cetaceans																		
Dall's porpoise	0.1450767	0.1610605	0.1131827	31,053	3,581	23,562	52,439	3,364			519	3,795	5,935	10,250	9,762	488	33.01	10,250
Otariid Seals																		
Northern fur seal	0.0109117	0.1297339	0.0099653	620,660	31,886	30,068	17,628	48	55	30	348	3,901	176	4,424	4,416	8	0.71	4,424
Guadalupe fur seal	*0.0234772*	*0.0262595*		34,187	15,136	64,446		516	113		355	1,692	0	2,048	2,033	15	5.99	2,048
California sea lion	0.0288000	0.0037000	0.0065000	257,606	18,356	13,530	47,696	28	20	86	529	50	310	889	888	1	0.35	889
Steller sea lion	0.4804893	0.0035811		77,149	15,136	64,446		516	113		7,273	231	0	7,504	7,255	249	9.73	7,504

APPENDIX C: NMFS CALCULATIONS OF SOUTHERN RESIDENT KILLER WHALE TAKES

APPENDIX C: NMFS CALCULATIONS OF SOUTHERN RESIDENT KILLER WHALE TAKES

In order to calculate estimated take, NMFS used the proposed seismic tracklines and overlaid them on density plots for Southern Resident killer whales created and provided by the U.S. Navy (USN 2019). Table C-1 shows the estimated ensonified areas within killer whale habitat, and Table C-2 shows the estimated takes.

TABLE C-1. Estimates of ensonified area within killer whale habitat and the killer whale density expected to occur there.

Pod	**Density (animals/km^2)**	**Ensonified Area (km^2)**
K/L	0	5,888
	0.000001 - 0.002803	15,470
	0.002804 - 0.005615	342
	0.005616 - 0.009366	0
	0.009367 - 0.015185	0
J	0	6,427
	0.000001 - 0.001991	5,556
	0.001992 - 0.005010	0
	0.005011 - 0.009602	0

TABLE C-2. Southern Resident Killer Whale takes as estimated by NMFS.

J pod			K/L pods			Total all pods US	Total all pods Canada	Total all areas
US	Canada territorial	Total	US	Canada territorial	Total			
1.27	0.24	1.51	8.01	0.6	8.61	9.28	0.84	10.12

Literature Cited

USN. 2019. U.S. Navy Marine Species Density Database Phase III for the Northwest Training and Testing Study Area. NAVFAC Pacific Technical Report. Naval Facilities Engineering Command Pacific, Pearl Harbor, HI. 262 p.

APPENDIX D: USFWS MMPA IHA & FEDERAL REGISTER NOTICE

United States Department of the Interior

FISH AND WILDLIFE SERVICE
911 NE 11th Avenue
Portland, Oregon 97232-4181

In Reply Refer to:
FWS/IR09/IR12/IHA-21-01

INCIDENTAL HARASSMENT AUTHORIZATION
(IHA-21-01)

The National Science Foundation and Lamont-Doherty Earth Observatory (NSF/L–DEO) are hereby authorized by the U.S. Fish and Wildlife Service (Service) under section 101(a)(5)(D) of the Marine Mammal Protection Act (MMPA; 16 U.S.C. 1371 (a)(5)(D)) to harass northern sea otters incidental to a marine geophysical survey along the coasts of Washington and Oregon, when adhering to the following terms and conditions.

1. This Incidental Harassment Authorization (IHA) is valid for a period of one year from the date of issuance.

2. This IHA is valid only for marine geophysical survey activity as specified in NSF/L–DEO's IHA application and draft environmental assessment, as subsequently modified in the Service's Federal Register notice (86 FR 12019, March 1, 2021) and the Service's final environmental assessment and Finding of No Significant Impact (FONSI); specifically using an airgun array towed behind the R/V *Langseth* and other sound emitting equipment abord the R/V *Langseth* and R/V *Oceanus* with characteristics specified in the IHA application along the Cascadia Subduction Zone off the coasts of Washington and Oregon.

3. General Conditions

   (a) A copy of this IHA shall be in the possession of NSF/L–DEO, the vessel operator, the lead Protected Species Observer (PSO) and any other relevant designees of NSF/L–DEO operating under the authority of this IHA. These personnel shall understand, be fully aware of, and be capable of full implementation of the terms and conditions of the IHA at all times during project work.

   (b) Operators shall allow Service personnel or the Service's designated representative to visit project work sites to monitor impacts to sea otters at any time throughout project activities so long as it is safe to do so. ''Operators'' are all personnel operating under the applicant's authority, including all contractors and subcontractors.

(c) Authorized incidental take is limited to a total of 13 northern sea otters. Take may be Level A harassment, Level B harassment, or combination. Authorized take shall be limited to significant injury associated with permanent threshold shifts and disruption of behavioral patterns that may be caused by geophysical surveys and support activities conducted by NSF/L–DEO in Washington and Oregon, from approximately May 20 to July 31, 2021. It is possible the proposed project timeframe could be delayed. However, as noted below, the authorization is valid for up to one year from the signature date.

(d) The taking by death of northern sea otter is prohibited and may result in the modification, suspension, or revocation of this IHA.

(e) The taking of sea otters whenever the required conditions, mitigation, monitoring, and reporting measures have not been fully implemented, as required by this IHA, is prohibited. Failure to follow measures specified herein may result in the modification, suspension, or revocation of this IHA.

(f) NSF/L–DEO or the vessel operator shall conduct briefings between PSOs and vessel crew prior to the start of all seismic operations, and when new personnel join the work, in order to explain responsibilities, communication procedures, northern sea otter monitoring protocol, and operational procedures.

4. Mitigation Measures

The holder of this Authorization is required to implement the following mitigation measures:

(a) Within the waters offshore of Washington between Tatoosh Island and the Quillayute River mouth, survey transects shall remain 21 km (13 mi) from shore or seaward of 100-m (328-ft) depth contour, whichever is greater. Survey transects shall remain seaward of the 100-m (328-ft) depth contour between the mouths of the Quillayute River and Grays Harbor. Waters less than 100-m depth contour offshore of Washington between Tatoosh Island and Grays Harbor constitute the area of highest sea otter densities within the proposed action.

(b) While the R/V *Langseth* is surveying in waters 200 m (656 ft) deep or less off the coast of Washington, survey operations shall occur in daylight hours only (*i.e.*, from 30 minutes prior to sunrise through 30 minutes following sunset) to ensure that observers are able to visually observe the entire 500-m (1,640-ft) Exclusion Zone (EZ) and beyond to implement shutdown procedures.

(c) If possible, while the R/V *Langseth* is surveying in waters 1,000 m (3,280 ft) deep or less off the coast of Washington, survey operations shall occur in daylight hours only (*i.e.*, from 30 minutes prior to sunrise through 30 minutes following sunset) to ensure that PSOs are able to visually observe the entire 500-m (1,640-ft) EZ and beyond to implement shutdown procedures.

(d) Vessel-Based Visual Observation

(i) NSF/L–DEO shall use at least five dedicated, trained, Service-approved PSOs. The PSOs shall have no tasks other than to conduct observational effort, record observational data, and communicate with and instruct relevant vessel crew with regard to the presence of northern sea otters and mitigation requirements.

(ii) At least one of the visual PSOs aboard the vessel shall have a minimum of 90 days at-sea experience working in those roles, respectively, during a deep-penetration (*i.e.*, "high energy") seismic survey, with no more than 18 months elapsed since the conclusion of the at-sea experience. One visual PSO with such experience shall be designated as the lead for the entire protected species observation team. The lead PSO shall serve as primary point of contact for the vessel operator and ensure all PSO requirements per the IHA are met. To the maximum extent practicable, the experienced PSOs shall be scheduled to be on duty with those PSOs with appropriate training but who have not yet gained relevant experience.

(iii) During survey operations (*e.g.*, any day on which use of the acoustic source is planned to occur, and whenever the acoustic source is in the water, whether activated or not), a minimum of two visual PSOs shall be on duty and conducting visual observations at all times during daylight hours (*i.e.*, from 30 minutes prior to sunrise through 30 minutes following sunset). Visual monitoring of the exclusion and buffer zones shall begin no less than 30 minutes prior to ramp-up and shall continue until 1 hour after use of the acoustic source ceases or until 30 minutes past sunset. Visual PSOs shall coordinate to ensure 360° visual coverage around the vessel from the most appropriate observation posts and shall conduct visual observations using binoculars and the naked eye while free from distractions and in a consistent, systematic, and diligent manner.

(iv) During use of the airgun (*i.e.*, anytime the acoustic source is active, including ramp-up), occurrences of northern sea otters within the buffer zone (but outside the exclusion zone) shall be communicated to the operator to prepare for the potential shutdown of the acoustic source. Visual PSOs shall immediately communicate all observations to the on-duty acoustic PSO(s), including any determination by the PSO regarding species identification, distance, and bearing and the degree of confidence in the determination. Any observations of northern sea otters by crew members shall be relayed to the PSO team. During good conditions (*e.g.*, daylight hours; Beaufort sea state (BSS) 3 or less), visual PSOs shall conduct observations when the acoustic source is not operating for comparison of sighting rates and behavior with and without use of the acoustic source and between acquisition periods, to the maximum extent practicable.

(v) Visual PSOs may be on watch for a maximum of 4 consecutive hours followed by a break of at least 1 hour between watches and may conduct a maximum of 12 hours of observation per 24-hour period.

(e) Exclusion zone and buffer zone

(i) PSOs shall establish and monitor a 500-m (1,640-ft) exclusion zone and 1,000-m (3,280-ft) buffer zone. The exclusion zone encompasses the area at and below the sea surface out to a radius of 500 m from the edges of the acoustic source (rather than being based on the center of the array or around the vessel itself). The buffer zone encompasses the area at and below the sea surface from the edge of the 0–500-m (1,640-ft) exclusion zone, out to a radius of 1,000 m (3,280 ft) from the edges of the airgun array (500–1,000 m [1,640–3,280 ft]). PSOs shall monitor up to 1,000 m and enumerate any incidental take that occurs.

(f) Pre-clearance and Ramp-up

(i) A ramp-up procedure shall be followed at all times as part of the activation of the acoustic source, except as described under 4(f)(ix).

(ii) The operator shall notify a designated PSO of the planned start of ramp-up as agreed upon with the lead PSO; the notification time should not be less than 60 minutes prior to the planned ramp-up in order to allow the PSOs time to monitor the exclusion and buffer zones for 30 minutes prior to the initiation of ramp-up (pre-clearance).

(iii) Ramp-ups shall be scheduled so as to minimize the time spent with the source activated prior to reaching the designated run-in.

(iv) One of the PSOs conducting pre-clearance observations shall be notified again immediately prior to initiating ramp-up procedures and the operator shall receive confirmation from the PSO to proceed.

(v) Ramp-up shall not be initiated if any northern sea otter is within the exclusion or buffer zone. If a sea otter is observed within the exclusion zone or the buffer zone during the 30 minute pre-clearance period, ramp-up may not begin until the animal(s) has been observed exiting the zone or until an additional 15-minute time period has elapsed with no further sightings.

(vi) Ramp-up shall begin by activating a single airgun of the smallest volume in the array and shall continue in stages by doubling the number of active elements at the commencement of each stage, with each stage of approximately the same duration. Duration shall not be less than 20 minutes. The operator shall provide information to the PSO documenting that appropriate procedures were followed.

(vii) Visual PSOs shall monitor the exclusion and buffer zones during ramp-up, and ramp-up shall cease and the source shall be shut down upon observation of a northern sea otter within the exclusion zone. Once ramp-up has begun, observations of northern sea otters within the buffer zone do not require shutdown, but such observation shall be communicated to the operator to prepare for the potential shutdown.

(viii) Ramp-up may occur at times of poor visibility if appropriate visual monitoring has occurred with no detections in the 30 minutes prior to beginning ramp-up. Acoustic source activation may occur only at times of poor visibility where operational planning cannot reasonably avoid such circumstances.

(ix) If the acoustic source is shut down for brief periods (*i.e.*, less than 30 minutes) for reasons other than that described for shutdown (*e.g.*, mechanical difficulty), it may be activated again without ramp-up if PSOs have maintained constant visual and/or acoustic observation and no visual or acoustic detections of northern sea otters have occurred within the applicable exclusion zone. For any longer shutdown, pre-clearance observation and ramp-up are required. For any shutdown at night or in periods of poor visibility (*e.g.*, BSS 4 or greater), ramp-up is required, but if the shutdown period was brief and constant visual observation was maintained, pre-clearance watch of 30 minutes is not required.

(x) Testing of the acoustic source involving all elements requires ramp-up. Testing limited to individual source elements or strings does not require ramp-up but does require pre-clearance of 30 minutes.

(g) Shutdown

(i) Any PSO on duty has the authority, and shall be required, to delay the start of survey operations or to call for shutdown of the acoustic source if a northern sea otter is detected within the 500-m exclusion zone.

(ii) The operator shall also establish and maintain clear lines of communication directly between PSOs on duty and crew controlling the acoustic source to ensure that shutdown commands are conveyed swiftly while allowing PSOs to maintain watch.

(iii) When the airgun array is active (*i.e.*, anytime one or more airguns is active, including during ramp-up) and a northern sea otter appears within or enters the 500-m exclusion zone, the acoustic source shall be shut down. When shutdown is called for by a PSO, the acoustic source shall be immediately deactivated.

(iv) Following a shutdown, airgun activity shall not resume until the northern sea otter(s) has been visually observed exiting the 500-m (1,640-ft) exclusion zone or it has not been seen within the 500-m (1,640-ft) exclusion zone for 15 minutes.

(v) L–DEO shall implement shutdown if a sea otter approaches the Level A or Level B harassment zones if the level of authorized incidental take has been met.

5. Monitoring Requirements

The holder of this Authorization is required to conduct northern sea otter monitoring during survey activity. Monitoring shall be conducted in accordance with the following requirements:

(a) The operator shall provide PSOs with bigeye binoculars (*e.g.*, 25×150; 2.7-view angle; individual ocular focus; height control) of appropriate quality (*i.e.*, Fujinon or equivalent) solely for PSO use. These shall be pedestal-mounted on the deck at the most appropriate vantage point that provides for optimal sea surface observation, PSO safety, and safe operation of the vessel.

(b) The operator shall work with the selected third-party observer provider to ensure PSOs have all equipment (including backup equipment) needed to adequately perform necessary tasks, including accurate determination of distance and bearing to observed sea otters.

(c) Visual Protected Species Observer (PSO) Qualifications

(i) PSOs shall be independent, dedicated, trained visual PSOs and shall be employed by a third-party observer provider.

(ii) PSOs shall have no tasks other than to conduct observational effort, collect data, and communicate with and instruct relevant vessel crew with regard to the presence of protected species (northern sea otters and those under the jurisdiction of NMFS) and mitigation requirements (including brief alerts regarding maritime hazards).

(iii) NSF and L–DEO are responsible for providing appropriate training to PSOs to ensure ability to observe and identify a sea otter.

(iv) NSF/L–DEO shall submit to the Service for review and approval PSO resumes including relevant training course information that identifies the name and qualifications (*i.e.*, experience, training completed, or educational background) of the instructor(s), the course outline or syllabus, and course reference material as well as a document stating successful completion of the course (passing a written and/or oral examination with 80 percent or greater).

(v) PSOs shall have successfully attained a bachelor's degree from an accredited college or university with a major in one of the natural sciences, a minimum of 30 semester hours or equivalent in the biological sciences, and at least one undergraduate course in math or statistics.

(vi) The educational requirements may be waived if the PSO has acquired the relevant skills through alternate experience. Requests for such a waiver shall be submitted to the Service and shall include written justification. Requests shall be granted or denied (with justification) by the Service within 1 week of receipt of submitted information. Alternate experience that may be considered includes, but is not limited to (1) secondary education and/or experience comparable to PSO duties; (2) previous work experience conducting academic, commercial, or government-sponsored protected species surveys; or (3) previous work experience as a PSO; the PSO should demonstrate good standing and consistently good performance of PSO duties.

(d) Data Collection

(i) PSOs shall use consistent data collection forms, whether hard copy or electronic. PSOs shall record detailed information about any implementation of mitigation requirements, including the distance of sea otters to the acoustic source and description of specific actions that ensued, the behavior of the animal(s), any observed changes in behavior before and after implementation of mitigation, and if shutdown was implemented, the length of time before any subsequent ramp-up of the acoustic source. If required mitigation was not implemented, PSOs should record a description of the circumstances.

(ii) At a minimum, the following information shall be recorded:

a. Vessel names (source vessel and other vessels associated with survey) and call signs.

b. PSO names and affiliations.

c. Dates of departures and returns to port with port name.

d. Date and participants of PSO briefings.

e. Dates and times (Greenwich Mean Time) of survey effort and times corresponding with PSO effort.

f. Vessel location (latitude/longitude) when survey effort began and ended and vessel location at beginning and end of visual PSO duty shifts.

g. Vessel heading and speed at beginning and end of visual PSO duty shifts and upon any line change.

h. Environmental conditions while on visual survey (at beginning and end of PSO shift and whenever conditions changed significantly), including BSS and any other relevant weather conditions including cloud cover, fog, sun glare, and overall visibility to the horizon.

i. Factors that may have contributed to impaired observations during each PSO shift change or as needed as environmental conditions changed (*e.g.*, vessel traffic, equipment malfunctions).

j. Survey activity information, such as acoustic source power output while in operation, number and volume of airguns operating in the array, tow depth of the array, and any other notes of significance (*i.e.*, pre-clearance, ramp-up, shutdown, testing, shooting, ramp-up completion, end of operations, streamers, etc.).

(iii) Upon visual observation of any northern sea otter, the following information shall be recorded:

a. Watch status (sighting made by PSO on/off effort, opportunistic, crew, alternate vessel/platform).

b. PSO who sighted the animal.

c. Time of sighting.

d. Vessel location at time of sighting.

e. Water depth.

f. Direction of vessel's travel (compass direction).

g. Direction and estimated distance of northern sea otter relative to the vessel at initial sighting.

h. Estimated number of animals (high/low/best).

i. Detailed behavior observations (*e.g.*, grooming; actively moving away from vessel; diving; note any observed changes in behavior).

j. Animal's closest point of approach and/or closest distance from any element of the acoustic source.

k. Platform activity at time of sighting (*e.g.*, deploying, recovering, testing, shooting, data acquisition, other).

l. Description of any actions implemented in response to the sighting (*e.g.*, delays, shutdown, ramp-up) and time and location of the action.

6. Reporting

(a) NSF/L–DEO shall submit a final report to the Service within 90 after completion of work or expiration of the IHA, whichever comes sooner. The final report shall include the following:

(i) Summary of the operations conducted and sightings of sea otters near the operations.

(ii) Full documentation of methods, results, and interpretation pertaining to all monitoring, including factors influencing visibility and detectability of sea otters.

(iii) Summary of dates and locations of seismic operations and all northern sea otter sightings (dates, times, locations, activities, associated seismic survey activities).

(iv) Estimates of the number and nature of northern sea otter exposures that occurred above the harassment threshold based on PSO observations.

(v) Geo-referenced time-stamped vessel transect lines for all time periods during which airguns were operating. Transect lines should include points recording any change in airgun status (*e.g.*, when the airguns began operating, when they were turned off, or when they changed from full array to single gun or vice versa).

(vi) GIS files shall be provided in ESRI shapefile format and include the UTC date and time, latitude in decimal degrees, and longitude in decimal degrees. All coordinates shall be referenced to the GCS_North_American_1983 geographic coordinate system.

(vii) All raw observational data.

(viii) Certification from the lead PSO as to the accuracy of the report.

a. The lead PSO may submit statement directly to the Service concerning implementation and effectiveness of the required mitigation and monitoring.

(b) Reporting Injured or Dead Northern Sea Otters

(i) Reporting of Injured or Dead Northern Sea Otter - In the event that personnel involved in survey activities covered by the authorization discover an injured or dead northern sea otter, the NSF/L–DEO shall report the incident to the Washington Fish and Wildlife Office's sea otter stranding coordinator (1-877-326-8837) as soon as feasible, but no later than within 48 hours. The report shall include the following information:

a. Time, date, and location (latitude/longitude) of the discovery.

b. Condition of the animal(s) (including carcass condition if the animal is dead).

c. Observed behaviors of the animal(s), if alive.

d. If available, photographs or video footage of the animal(s).

e. General circumstances under which the animal was discovered.

(ii) Vessel Strike - In the event of a ship strike of a northern sea otter by any vessel involved in the activities covered by the authorization, NSF/L–DEO shall report the incident to Washington Fish and Wildlife Office's sea otter stranding coordinator (contact information above) as soon as feasible. The report shall include the following information:

a. Time, date, and location (latitude/longitude) of the incident.

b. Vessel's speed during and leading up to the incident.

c. Vessel's course/heading and what operations were being conducted (if applicable).

d. Status of all sound sources in use.

e. Description of avoidance measures/requirements that were in place at the time of the strike and what additional measures were taken, if any, to avoid strike.

f. Environmental conditions (*e.g.*, wind speed and direction, Beaufort sea state, cloud cover, visibility) immediately preceding the strike.

g. Description of the behavior of the northern sea otter immediately preceding and following the strike.

h. Estimated fate of the animal (*e.g.*, dead, injured but alive, injured and moving, blood or tissue observed in the water, status unknown, disappeared).

i. To the extent practicable, photographs or video footage of the animal(s).

(iii) *Additional Information Requests*—If the Service determines that the circumstances of any northern sea otter stranding found in the vicinity of the activity suggest investigation of the association with survey activities is warranted (example circumstances noted below), and an investigation into the stranding is being pursued, the Service shall submit a written request to the IHA-holder indicating that the following initial available information shall be provided as soon as possible, but no later than 7 business days after the request for information.

a. Status of all sound source use in the 48 hours preceding the estimated time of stranding and within 50 km (31 mi) of the discovery/notification of the stranding by the Service.

b. If available, description of the behavior of any sea otters(s) observed preceding (*i.e.*, within 48 hours and 50 km [31 mi]) and immediately after the discovery of the stranding.

c. Examples of circumstances that could trigger the additional information request include, but are not limited to, the following:

   1. Necropsies with findings of pathologies that are unusual for northern sea otters.

   2. Stranded animals with findings consistent with blast trauma.

d. In the event that the investigation is still inconclusive, the investigation of the association of the survey activities is still warranted, and the investigation is still being pursued, the Service may provide additional information requests, in writing, regarding the nature and location of survey operations prior to the time period above.

7. This Authorization may be modified, suspended or withdrawn if the holder fails to abide by the conditions prescribed herein, or if the Service determines the authorized taking is having more than a negligible impact on the northern sea otter stock in Washington and Oregon.

8. Renewals - On a case-by-case basis, the Service may issue a one-year IHA renewal with an expedited public comment period (15 days) when 1) another year of identical or nearly identical activities as described in the Specified Activities section is planned or 2) the activities would not be completed by the time the IHA expires and a second IHA would allow for completion of the activities beyond that described in the Dates and Duration section, provided all of the following conditions are met:

   (a) A request for renewal is received no later than 60 days prior to expiration of the current IHA.

   (b) The request for renewal shall include the following:

(i) An explanation that the activities to be conducted beyond the initial dates either are identical to the previously analyzed activities or include changes so minor (e.g., reduction in transects) that the changes do not affect the previous analyses, incidental take estimates, or mitigation and monitoring requirements.

(ii) A preliminary monitoring report showing the results of the required monitoring to date and an explanation showing that the monitoring results do not indicate impacts of a scale or nature not previously analyzed or authorized.

(iii) Upon review of the request for renewal, the status of the northern sea otter, and any other pertinent information, the Service determines that there are no more than minor changes in the activities, the mitigation and monitoring measures remain the same and appropriate, and the original findings remain valid.

9. All reports or inquiries shall be submitted to "Attention: Washington Fish and Wildlife Office's Sea Otter Stranding Coordinator" at WashingtonFWO_Admin@fws.gov.

Acting
Hugh Morrison

Digitally signed by Hugh Morrison
Date: 2021.04.20 16:56:39 -07'00'

Regional Director, Interior Regions 9 and 12
U.S. Fish and Wildlife Service

April 20, 2021

Date

for purposes of publication in the **Federal Register**.

Aaron Santa Anna,

Federal Register Liaison for the Department of Housing and Urban Development.

[FR Doc. 2021–04074 Filed 2–26–21; 8:45 am]

BILLING CODE 4210–67–P

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

[Docket No. FR–7040–N–04; OMB Control No. 2535–0107]

60-Day Notice of Proposed Information Collection: Public Housing Financial Management Template

AGENCY: Office of the Assistant Secretary for Public and Indian Housing, PIH, HUD.

ACTION: Notice.

SUMMARY: HUD is seeking approval from the Office of Management and Budget (OMB) for the information collection described below. In accordance with the Paperwork Reduction Act, HUD is requesting comment from all interested parties on the proposed collection of information. The purpose of this notice is to allow for 60 days of public comment.

DATES: *Comments Due Date: April 30, 2021.*

ADDRESSES: Interested persons are invited to submit comments regarding this proposal. Comments should refer to the proposal by name and/or OMB Control Number and should be sent to: Colette Pollard, Reports Management Officer, QDAM, Department of Housing and Urban Development, 451 7th Street SW, Room 4176, Washington, DC 20410–5000; telephone 202–402–5564 (this is not a toll-free number) or email at *Colette.Pollard@hud.gov* for a copy of the proposed forms or other available information. Persons with hearing or speech impairments may access this number through TTY by calling the toll-free Federal Relay Service at (800) 877–8339.

FOR FURTHER INFORMATION CONTACT: Dacia Rogers, Office of Policy, Programs and Legislative Initiatives, PIH, Department of Housing and Urban Development, 451 7th Street SW, (L'Enfant Plaza, Room 2206), Washington, DC 20410; telephone 202–402–4109, (this is not a toll-free number). Persons with hearing or speech impairments may access this number via TTY by calling the Federal Relay Service at (800) 877–8339. Copies of available documents submitted to OMB may be obtained from Ms. Rogers.

SUPPLEMENTARY INFORMATION: This notice informs the public that HUD is seeking approval from OMB for the information collection described in Section A.

A. Overview of Information Collection

Title of Information Collection: Public Housing Financial Management Template.

OMB Approval Number: 2535–0107.

Type of Request: Reinstatement of a previously approved collection.

Form Number: N/A.

Description of the need for the information and proposed use: To meet the requirements of the Uniform Financial Standards Rule (24 CFR part 5, subpart H) and the asset management requirements in 24 CFR part 990, the Department developed financial management templates that public housing agencies (PHAs) use to annually submit electronically financial information to HUD. HUD uses the financial information it collects from each PHA to assist in the evaluation and assessment of the PHAs' overall condition. Requiring PHAs to report electronically has enabled HUD to provide a comprehensive financial assessment of the PHAs receiving federal funds from HUD.

Respondents: Public Housing Agencies (PHAs).

Estimated Annual Reporting and Recordkeeping Burden: The average burden hour estimate assumes that there are 3,916 PHAs (Low Rent Only, Low Rent and Section 8, and Section 8 only PHAs) that submit one unaudited financial management template annually. The average burden hours associated with an unaudited financial management template is 6.4 hours (25,015.5 total hours divided by 3,916 PHAs). There are 3,538 PHAs that are required to or voluntarily submit an audited financial management template annually. The average burden hours associated with an audited financial management template is 4.2 hours (14,705 total hours divided by 3,538 PHAs). When added together, the average burden hours for a PHA that submits both an unaudited and audited financial management template is 5.3 hours, for a total reporting burden of 39,721 hours.

B. Solicitation of Public Comment

This notice is soliciting comments from members of the public and affected parties concerning the collection of information described in Section A on the following:

(1) Whether the proposed collection of information is necessary for the proper performance of the functions of the agency, including whether the information will have practical utility;

(2) The accuracy of the agency's estimate of the burden of the proposed collection of information;

(3) Ways to enhance the quality, utility, and clarity of the information to be collected; and

(4) Ways to minimize the burden of the collection of information on those who are to respond; including through the use of appropriate automated collection techniques or other forms of information technology, *e.g.*, permitting electronic submission of responses.

HUD encourages interested parties to submit comment in response to these questions.

C. Authority

Section 3507 of the Paperwork Reduction Act of 1995, 44 U.S.C. Chapter 35 as amended.

Dated: February 19, 2021.

Merrie Nichols-Dixon,

Director, Office of Policy, Programs and Legislative Initiatives.

[FR Doc. 2021–04136 Filed 2–26–21; 8:45 am]

BILLING CODE 4210–67–P

DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

[Docket No. FWS–R1–ES–2020–0131; FXES111401000000, 212, FF01E00000]

Marine Mammals; Incidental Take During Specified Activities; Proposed Incidental Harassment Authorization for Northern Sea Otters in the Northeast Pacific Ocean

AGENCY: Fish and Wildlife Service, Interior.

ACTION: Notice of receipt of application and proposed incidental harassment authorization; availability of draft environmental assessment; and request for public comments.

SUMMARY: The U.S. Fish and Wildlife Service (Service) received a request from the National Science Foundation (NSF) for authorization to take a small number of northern sea otters by harassment incidental to a marine geophysical survey in the northeast Pacific Ocean. Pursuant to the Marine Mammal Protection Act of 1972, as amended (MMPA), the Service is requesting comments on its proposal to issue an incidental harassment authorization (IHA) to NSF for certain activities during the period between May 1 and June 30, 2021. This proposed IHA, if finalized, will be for take by Level A and Level B harassment. We

anticipate no take by death and include none in this proposed authorization. The Service has prepared a draft environmental assessment (EA) addressing the proposed IHA and is soliciting public comments on both documents.

DATES: Comments on the proposed IHA request and the draft EA will be accepted on or before March 31, 2021.

ADDRESSES:

Document availability: The proposed IHA request, the draft EA, and the list of references cited herein are available for viewing at *http://www.regulations.gov* in Docket No. FWS–R1–ES–2020–0131 and at *http://www.fws.gov/wafwo*. NSF's associated environmental assessments can be found at *https://www.nsf.gov/geo/oce/envcomp/*.

Comment Submission: You may submit comments on this proposed authorization by one of the following methods:

- *U.S Mail:* Public Comments Processing, Attn: Docket No. FWS–R1–ES–2020–0131, U.S. Fish and Wildlife Service, 5275 Leesburg Pike, MS: PRB/3W, Falls Church, VA 22041–3803; or
- *Federal eRulemaking Portal: http://www.regulations.gov*. Follow the instructions for submitting comments to Docket No. FWS–R1–ES–2020–0131.

We will post all comments on *http://www.regulations.gov*. You may request that we withhold personal identifying information from public review; however, we cannot guarantee that we will be able to do so. See Request for Public Comments for more information.

FOR FURTHER INFORMATION CONTACT: Brad Thompson, State Supervisor, U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, 510 Desmond Drive SE, Suite 102, Lacey, WA 98503–1273 (telephone 360–753–9440).

SUPPLEMENTARY INFORMATION:

Background

Section 101(a)(5)(D) of the Marine Mammal Protection Act of 1972, as amended (MMPA; 16 U.S.C. 1361, *et seq.*), authorizes the Secretary of the Interior to allow, upon request, the incidental, but not intentional, taking of small numbers of marine mammals by U.S. citizens who engage in a specified activity (other than commercial fishing) within a specified region during a period of not more than 1 year. Incidental take may be authorized only if statutory and regulatory procedures are followed and the U.S. Fish and Wildlife Service (hereafter, "the Service" or "we") makes the following findings: (i) The take is of a small number of marine mammals; (ii) the take will have a negligible impact on the species or stock; and (iii) take will not have an unmitigable adverse impact on the availability of the species or stock for subsistence uses by coastal-dwelling Alaska Natives. As part of the authorization process, we prescribe permissible methods of taking and other means of affecting the least practicable impact on the species or stock and its habitat and prescribe requirements pertaining to the monitoring and reporting of such takings.

The term "take," as defined by the MMPA, means to harass, hunt, capture, or kill, or to attempt to harass, hunt, capture, or kill any marine mammal (16 U.S.C. 1362(13)). Harassment, as defined by the MMPA, means "any act of pursuit, torment, or annoyance which (i) has the potential to injure a marine mammal or marine mammal stock in the wild (the MMPA refers to this impact as Level A harassment) or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering (the MMPA refers to these impacts as Level B harassment) (See 16 U.S.C. 1362(18)).

The terms "negligible impact," "small numbers," and "unmitigable adverse impact" are defined in the Code of Federal Regulations at 50 CFR 18.27, the Service's regulations governing take of small numbers of marine mammals incidental to specified activities. "Negligible impact" is defined as an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival. "Small numbers" is defined as a portion of a marine mammal species or stock whose taking would have a negligible impact on that species or stock. However, we do not rely on that definition as it conflates the terms "small numbers" and "negligible impact," which we recognize as two separate and distinct requirements (see *Natural Res. Def. Council, Inc.* v. *Evans*, 232 F. Supp. 2d 1003, 1025 (N.D. Cal. 2003)). Instead, in our small numbers determination, we evaluate whether the number of marine mammals likely to be taken is small relative to the size of the overall population. "Unmitigable adverse impact" is defined as an impact resulting from the specified activity (1) that is likely to reduce the availability of the species to a level insufficient for a harvest to meet subsistence needs by (i) causing the marine mammals to abandon or avoid hunting areas, (ii) directly displacing subsistence users, or (iii) placing physical barriers between the marine mammals and the subsistence hunters; and (2) that cannot be sufficiently mitigated by other measures to increase the availability of marine mammals to allow subsistence needs to be met. The subsistence provision does not apply to northern sea otters in Washington and Oregon.

If the requisite findings are made, we will issue an IHA, which sets forth the following: (i) Permissible methods of taking; (ii) other means of effecting the least practicable impact on marine mammals and their habitat, paying particular attention to rookeries, mating grounds, and areas of similar significance; and (iii) requirements for monitoring and reporting take.

Summary of Request

On December 19, 2019, the Service received an application from the National Science Foundation (hereafter "NSF" or "the applicant") for authorization to take the northern sea otter (*Enhydra lutris kenyoni*, hereafter "sea otters" or "otters" unless another subspecies is specified) by unintentional harassment incidental to a marine geophysical survey of the Cascadia Subduction Zone off the coasts of Washington, Oregon, and British Columbia, Canada. The NSF subsequently postponed the project until 2021.

Description of the Activities and Specified Geographic Region

The specified activity (the "project") consists of Lamont-Doherty Earth Observatory's (L–DEO) 2020 Marine Geophysical Surveys by the Research Vessel *Marcus G. Langseth* (R/V *Langseth*) in the Northeast Pacific Ocean between May 1 and June 31, 2021. The high-energy, two-dimensional (2–D) seismic surveys are expected to last for a total of 40 (nonconsecutive) days, including approximately 37 days of seismic operations, 2 days of equipment deployment/retrieval, and 1 day of transit. A maximum of 6,890 km (4,281 mi) of transect lines would be surveyed in marine waters adjacent to Oregon, Washington, and British Columbia from 41° N to 50° N latitude and − 124 N and − 130 W longitude, of which approximately 6,600 km (4,101 mi) would be in the U.S. Exclusive Economic Zone and 295 km (183 mi) in Canadian territorial waters. The Service cannot authorize the incidental take of marine mammals in waters not under the jurisdiction of the United States, and the Washington stock of the northern sea otter is not found within Canadian territorial waters. Therefore, the

Service's calculation of estimated incidental take is limited to the specified activity occurring in United States jurisdictional waters within the stock's range.

The survey would include several strike lines, parallel (including one continuous line along the continental shelf) and perpendicular to the coast. The R/V *Langseth* will tow 4 strings containing an array of 36 airguns at a depth of 12 m (39 ft), creating a discharge volume of approximately 6,600 cubic inches (in^3) or 0.11 cubic meter (m^3) at a shot interval of 37.5 m (123 ft). The 36-airgun array could operate 24 hours a day, except during mitigation shutdowns, for the entirety of the 37 days of survey. The energy produced by the seismic array is broadband and ranges from a few hertz (Hz) to kilohertz (kHz); however, all but a small fraction of the energy is focused in the 10–300 Hz range (Tolstoy *et al.* 2009). The receiving system would consist of one 15-km (9.3-mi) long hydrophone streamer, Ocean Bottom Seismometers (OBSs), and Ocean Bottom Nodes (OBNs) deployed within the survey area. In addition to the operations of the airgun array, a multibeam echosounder, a single-beam dual-frequency echosounder (4 and 12 kHz), a sub-bottom profiler (SBP), and an Acoustic Doppler Current Profiler (ADCP) would be operated. Further information and technical specifications can be found in NSF's IHA application and the Service's draft EA available at: *http://www.regulations.gov*, Docket No. FWS–R1–ES–2020–2012;0131.

Description of Northern Sea Otters in the Specified Activity Area

The proposed area of specified activity occurs within the range of the Washington stock of the northern sea otter, a portion of the species' range that is not listed under the Endangered Species Act of 1973, as amended (ESA). This stock primarily occurs along the Washington coast between Cape Flattery and Grays Harbor, but small groups have been reported in the Straits of Juan de Fuca and individual sea otters have been reported in Puget Sound and along the Oregon coast as far south as Cape Blanco (Jeffries *et al.* 2019, USFWS 2018, unpublished observations J. Rice OSU). Among the largest members of the family Mustelidae but one of the smallest of marine mammals, northern sea otters exhibit limited sexual dimorphism (males are larger than females) and can attain weights and lengths up to 40 kg (110 lb) and 1.4 m (4.6 ft), respectively. They have a typical life span of 11–15 years (Riedman and Estes 1990). Unlike most other marine mammals, sea otters have little subcutaneous fat. They depend on their clean, dense, water-resistant fur for insulation against the cold and maintain a high level of internal heat production to compensate for their lack of blubber. Consequently, their energetic requirements are high, and they consume an amount of food equivalent to approximately 23 to 33 percent of their body weight per day (Riedman and Estes 1990).

Northern sea otters forage in both rocky and soft-sediment communities in water depths of 40 m (131 ft) or less (Laidre *et al.* 2009), although otters have been documented along the Washington coast as far as 58 km (36 mi) offshore in waters deeper than 200 m (656 ft) (Pearson 2019; supplemental data provided to USFWS). They tend to be found closer to shore during storms, but they venture farther out during good weather and calm seas (Kenyon 1975). Sea otters occasionally make dives of up to 100 m (328 ft) (Newby 1975), but the vast majority of feeding dives (more than 95 percent) occur in waters less than 40 m (131 ft) in depth (Tinker *et al.* 2006). Therefore, sea otter habitat is typically defined by the 40-m (131-ft) depth contour (Laidre *et al.* 2011).

The number of sea otters in this stock, for the purposes of this analysis, was estimated to be approximately 3,000, based on survey count data and projections for areas not surveyed. The estimated minimum abundance of the stock, based on survey count data, was 2,785 sea otters within the area between Cape Flattery and Grays Harbor, Washington, between shore and the 40-m (131-ft) depth contour (Jeffries *et al.* 2019). While systematic surveys farther offshore have not been conducted in Washington or Oregon, otters have been documented farther offshore (Pearson 2019). Surveys conducted in Southeast Alaska found 95 percent of northern sea otters were found in areas shallower than 40-m (131 ft) and 5 percent farther offshore (Tinker *et al.* 2019). Therefore, assuming a similar proportion of sea otters in Washington occur offshore, we added 5 percent (139 sea otters) to the minimum abundance to account for otters farther offshore than 40-m (131-ft) depth contour, to get a total population estimate of 2,924 for the area between Cape Flattery and Grays Harbor. Based on best professional judgment and limited anecdotal observations, we estimate two sea otters would be somewhere along the coast between Grays Harbor and the Washington/Oregon border and two sea otters would be somewhere along the Oregon coast.

Otter densities were calculated for the area between Cape Flattery and Grays Harbor, broken down to north and south of the Quillayute River. Surveys indicate the otter population is not evenly distributed throughout the area surveyed (Jeffries *et al.* 2019), and the distribution of the population during the proposed project is likely to be similar to that detected during surveys, as work will occur during the same time of year as the surveys were conducted. (See Table 2 for density estimations). A density was not estimated for the area between Grays Harbor and the southern end of the project; rather, we assumed that the four sea otters estimated to occur there would be exposed.

Further biological information on this stock can be found in the Washington Department of Fish and Wildlife's Periodic Status Review (Sato 2018) and Recovery Plan (Lance *et al.* 2004). The sea otters in this stock have no regulatory status under the ESA. The potential biological removal (PBR) for this stock is 18 sea otters (USFWS 2018). PBR is defined by the MMPA as the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population. While no mortality is anticipated or authorized here, PBR is included as a gross indicator of the status of the species.

Sea Otter Hearing

Controlled sound exposure trials on a single older male southern sea otter (*E. l. nereis*) indicate that otters can hear frequencies between 125 Hz and 38 kHz with best sensitivity between 1.2 and 27 kHz in air and 2 to 26 kHz underwater; however, these thresholds may underrepresent best hearing capabilities in younger otters (Ghoul and Reichmuth 2014). Aerial and underwater audiograms for a captive adult (14-year-old) male southern sea otter in the presence of ambient noise suggest the sea otter's hearing was less sensitive to high-frequency (greater than 22 kHz) and low-frequency (less than 1 kHz) sound than terrestrial mustelids, but was similar to that of a California sea lion (*Zalophus californianus*). However, the subject otter was still able to hear low-frequency sounds, and the detection thresholds for sounds between 0.125–1 kHz were between 116–101 dB, respectively. Dominant frequencies of southern sea otter vocalizations are between 3 and 8 kHz, with some energy extending above 60 kHz (McShane *et al.* 1995; Ghoul and Reichmuth 2012).

Potential Impacts of the Proposed Seismic Survey on Northern Sea Otters in Washington and Oregon

This section includes a summary of the ways that components of the specified activity may impact sea otters and their habitat. A more in-depth analysis can be found in the Service's draft EA (USFWS 2020). The *Estimated Take by Incidental Harassment of Sea Otters* section later in this document includes a quantitative analysis of the number of sea otters that are expected to be taken by this activity. The *Negligible Impact* section considers the content of the *Estimated Take by Incidental Harassment of Sea Otters* section, and the *Mitigation and Monitoring* section, to draw conclusions regarding the likely impacts of these activities on the reproductive success or survivorship of individuals and how those impacts on individuals are likely to impact sea otters.

Otters may be impacted while at the surface by the presence of the vessels traveling to/from the ports to the transects and operating along the transects. Otters underwater may be impacted by the OBS/OBNs as they are deployed and the acoustic effects from the airguns, OBS/SBP/ADCP/ echosounders, and ship noise.

Anthropogenic sounds cover a broad range of frequencies and sound levels and can have a range of highly variable impacts on marine life, from none or minor to potentially severe responses, depending on signal characteristics, received levels, duration of exposure, behavioral context, and whether the sea otter is above or below the water surface. Underwater sounds are not likely to affect sea otters at the surface, due to the pressure release effect. Thus, the susceptibility of sea otters from underwater sounds would be restricted to behaviors during which the head or body is submerged, such as during foraging dives and underwater swimming and, intermittently, during grooming bouts. The proposed activities include underwater sound sources that are impulsive (airguns) and non-impulsive (OBS/SBP/ADCP/ echosounders and ship noise). Potential effects from impulsive sound sources can range in severity from effects such as behavioral disturbance or tactile perception to physical discomfort, slight to severe injury of the internal organs and the auditory system, or mortality (Yelverton *et al.* 1973; Yelverton and Richmond 1981; Turnpenny and Nedwell 1994; Turnpenny *et al.* 1994).

Marine mammals exposed to high-intensity sound, or to lower-intensity sound for prolonged periods, can experience a hearing threshold shift (TS), which is the loss of hearing sensitivity at certain frequency ranges (Finneran 2015). TS can be permanent (PTS), in which case there is physical damage to the sound receptors in the ear (*i.e.*, tissue damage) and the loss of hearing sensitivity is not fully recoverable, or temporary (TTS), in which case there is primarily tissue fatigue and the animal's hearing threshold would recover over time (Southall *et al.* 2007). Repeated sound exposure that leads to TTS could cause PTS. Temporary or permanent loss of hearing will occur almost exclusively for noise within an animal's hearing range. Given the longer exposure duration necessary to cause PTS as compared with TTS, it is considerably less likely that PTS would occur as a result of project activities because a sea otter could remove itself from exposure by coming to the surface. However, a sea otter underwater in close proximity to the higher level of sound could experience PTS. In addition, otters startled by the sound while foraging in deeper waters will be underwater longer and potentially be exposed to more acoustic sound.

Behavioral disturbance may include a variety of effects, including subtle changes in behavior (*e.g.*, minor or brief avoidance of an area, changes in vocalizations, or changes in antipredator response), more conspicuous changes in similar behavioral activities, and more sustained and/or potentially severe reactions, such as displacement from or abandonment of high-quality habitat. Reactions by sea otters to anthropogenic noise can be manifested as visible startle responses, flight responses (flushing into water from haulouts or "splash-down" alarm behavior in surface-resting rafts), changes in moving direction and/ or speed, changes in or cessation of certain behaviors (such as grooming, socializing, or feeding), or avoidance of areas where noise sources are located. The biological significance of these behavioral disturbances is difficult to predict, especially if the detected disturbances appear minor. However, the consequences of behavioral modification would be expected to be biologically significant if the change affected growth, survival, or reproduction.

Potentially significant behavioral modifications include disturbance of resting sea otters, marked disruption of foraging behaviors, separation of mothers from pups, or disruption of spatial and social patterns (sexual segregation and male territoriality). Foraging is energetically costly to sea otters, more so than other marine mammals, because of their buoyancy and swimming style (Yeates *et al.* 2007), thus displacement from or reduction of foraging in high-quality habitat could result in increased energy expenditures. The energy expense and associated physiological effects could ultimately lead to reduced survival and reproduction (Gill and Sutherland 2000; Frid and Dill 2002).

Disturbances can also have indirect effects; for example, response to noise disturbance is considered a nonlethal stimulus that is similar to an antipredator response (Frid and Dill 2002). Sea otters are susceptible to predation, particularly from sharks and eagles, and have a well-developed antipredator response to perceived threats, which includes actively looking above and beneath the water. Although an increase in vigilance or a flight response is nonlethal, a tradeoff occurs between risk avoidance and energy conservation. An animal's reactions to noise disturbance may cause stress and direct an animal's energy away from fitness-enhancing activities such as feeding and mating (Frid and Dill 2002; Goudie and Jones 2004). For example, southern sea otters in areas with heavy recreational boat traffic demonstrated changes in behavioral time budgeting showing decreased time resting and changes in haul-out patterns and distribution (Benham 2006; Maldini *et al.* 2012).

Chronic stress can also lead to weakened reflexes, lowered learning responses (Welch and Welch 1970; van Polanen Petel *et al.* 2006), compromised immune function, decreased body weight, and abnormal thyroid function (Seyle 1979). Changes in behavior resulting from anthropogenic disturbance can include increased agonistic interactions between individuals or temporary or permanent abandonment of an area (Barton *et al.* 1998). The type and extent of response may be influenced by intensity of the disturbance (Cevasco *et al.* 2001), the extent of previous exposure to humans (Holcomb *et al.* 2009), the type of disturbance (Andersen *et al.* 2012), and the age or sex of the individuals (Shaughnessy *et al.* 2008; Holcomb *et al.* 2009).

Exposure Thresholds—Although no specific thresholds have been developed for sea otters, several alternative behavioral response thresholds have been developed for otariid pinnipeds. Otariid pinnipeds (*e.g.*, California sea lions [*Zalophus californianus*]) have a frequency range of hearing most similar to that measured in a southern sea otter (Ghoul and Reichmuth 2014) and provide the closest related proxy for which data are available. Sea otters and pinnipeds share a common mammalian aural physiology (Echteler *et al.* 1994; Solntseva 2007). Both are adapted to amphibious hearing, and both use sound in the same way (primarily for communication rather than feeding). NMFS criteria for Level A harassment represents the best available information for predicting injury from exposure to underwater sound among pinnipeds, and in the absence of data specific to otters, we assume these criteria also represent appropriate exposure thresholds for Level A harassment of sea otters.

For otariid pinnipeds, PTS is predicted to occur at 232 dB peak or 203 dB SELcum (cumulative sound exposure level) for impulsive sound, or 219 dB SELcum for non-impulsive (continuous) sound (NMFS 2018). Exposure to unmitigated in-water noise levels between 125 Hz and 38 kHz that are greater than 232 dB peak or 203 dB SELcum for impulsive sound or 219 dB SELcum for non-impulsive (continuous) sound will be considered by the Service as Level A harassment. NMFS predicts that marine mammals are likely to be behaviorally harassed in a manner considered Level B harassment when exposed to underwater anthropogenic noise above received levels of 120 dB re 1 μPa (rms) for continuous (*e.g.*, vibratory pile-driving, drilling) and above 160 dB re 1 μPa (rms) for non-explosive impulsive (*e.g.*, seismic airguns) or intermittent (*e.g.*, scientific sonar) sources (NMFS 2018).

Thresholds based on TTS can be used as a proxy for Level B harassment. Based on studies summarized by Finneran (2015), NMFS (2018) has set the TTS threshold for otariid pinnipeds at 188 dB SELcum for impulsive sounds and 199 dB SELcum for non-impulsive sounds. Thus, using information available for other marine mammals, specifically otariid pinnipeds, as a surrogate, and taking into consideration the best available information about sea otters, the Service has set the received sound level underwater of 160 dB re 1 μPa (rms) as a threshold for Level B harassment for sea otters based on the work of Ghoul and Reichmuth (2012), McShane *et al.* (1995), Riedman (1983), Richardson *et al.* (1995), and others. Exposure to unmitigated impulsive in-water noise levels between 125 Hz and 38 kHz that are greater than 160 dB re 1 μPa (rms) will be considered by the Service as Level B harassment.

Exposure to Project Activities—Based on the studies on sea otters in Washington, California, and Alaska, we believe sea otters spend between 40 and 60 percent of a 24-hour period with at least a portion of their body underwater (foraging, other diving, or grooming behaviors that result in the head being underwater) and forage both diurnally and nocturnally (Esslinger *et al.* 2014, Laidre *et al.* 2009, Yeates *et al.* 2007, Tinker *et al.* 2008). Seismic survey activities can operate 24 hours/day and otters may be exposed at any time. Any single point along the transects could be above thresholds for a maximum of 6.5 hours, during which time sea otters in that area would engage in underwater behaviors and would be exposed to underwater sound. Some areas along the transects will be ensonified more than once.

Because sea otters spend a considerable portion of their time at the surface of the water, they are typically visually aware of approaching boats and are able to move away if the vessel is not traveling too quickly. The noise of approaching boats provides an additional warning, thus otters should be able to detect the vessels and paddle away, rather than be startled and go subsurface. Because the R/V *Langseth* would be traveling relatively slowly (4.5 knots) during the surveys, it is unlikely that sea otters would suffer injury or death from a vessel collision. Otters that may be foraging may be startled by the remotely operated vehicle deployed to retrieve OBNs in waters >60 m (197 ft) along three transects perpendicular to the Oregon coast.

The potential for exposure to all activities is likely to be limited to where the vessel is operating in waters <1,000 m (3,280 ft) deep, as we do not anticipate otters to be farther offshore. Off the Washington coast, females primarily forage and rest in waters <40 m (131 ft), but males spend less time foraging close to shore and rest farther offshore than females (Laidre *et al.* 2009), venturing as far offshore as 58 km (36 mi) (Pearson 2019). Within the waters adjacent to Washington and northern Oregon (to Tillamook Head), the ensonified zone would not penetrate the waters between shore and the 40-m (131-ft) depth contour, thus sea otters that may be exposed are more likely to be the males that occur farther offshore. The otters along the Oregon coast are presumed to be males, based on stranding data (FWS unpublished data).

NSF and L–DEO have proposed measures to minimize the chances of sea otter exposure to the seismic surveys. Along the Washington coast in waters <200 m (656 ft) deep, the airgun array would operate only during daylight hours. The airgun startup would be ramped in order to alert otters that are underwater, in the hope they would move away. Prior to airgun startup and during airgun operations, visual observers would be employed during daylight hours, in order to establish a 500-m (1,640 ft) exclusion zone. Any sea otter observed in this zone would lead to a shutdown of the airgun array. However, there will be gaps in the visual coverage, in particular during nighttime operations in Oregon and beyond 200 m (656 ft) in Washington. In addition, under poor weather conditions and some good weather conditions, observers cannot be 100 percent effective and may not detect a sea otter in, or about to enter, the exclusion zone. Further, visual observations cannot cover the entirety of the area with sound levels that may cause behavioral changes. The lack of ability to fully monitor the ensonified area means an otter(s) may go unobserved and be exposed to underwater noise that results in Level A and/or Level B harassment.

Potential Effects of the Proposed Activity on Northern Sea Otter Habitat

Physical and biological features of habitat essential to the conservation of sea otters include the benthic invertebrates (crabs, urchins, mussels, clams, etc.) eaten by otters and the shallow rocky areas and kelp beds that provide cover from predators. Important sea otter habitat areas of significance in the NSF and L–DEO project area include coastal areas within the 40-m (131-ft) depth contour where high densities of otters have been detected, although deeper waters may be important for male sea otters. A number of recent reviews and empirical studies have addressed the effects of noise on invertebrates (Carroll *et al.* 2017), sea otter prey, with some studies showing little or no effects and others indicating deleterious effects from exposure to increased sound levels. Given the short-term duration of sounds produced by each component of the proposed project, it is unlikely that noises generated by survey activities will have any lasting effect on sea otter prey (see the Service's draft EA (USFWS 2020) for further information). The MMPA allows the Service to identify avoidance and minimization measures for affecting the least practicable impact of the specified activity on important habitats. Although sea otters within this important habitat may be impacted by geophysical surveys conducted by NSF and L–DEO, the project, as currently proposed, is not likely to cause lasting effects to habitat.

Potential Impacts of the Proposed Activity on Subsistence Needs

The subsistence provision of the MMPA does not apply to northern sea otters in Washington and Oregon.

Mitigation and Monitoring

In order to issue an IHA under Section 101(a)(5)(D) of the MMPA, the Service must set forth the permissible methods of taking pursuant to the activity, and other means of affecting the least practicable impact on the species or stock and its habitat, paying particular attention to habitat areas of significance and the availability of sea otters for subsistence uses by coastal-dwelling Alaska Natives, although this factor is not applicable for this action.

In evaluating how mitigation may or may not be appropriate to ensure the least practicable impact on species or stocks and their habitat, as well as subsistence uses where applicable, we carefully consider two primary factors:

(1) The manner in which, and the degree to which, the successful implementation of the measure(s) is expected to reduce impacts to marine mammals, marine mammal species or stocks, and their habitat. This considers the nature of the potential adverse impact being mitigated (*i.e.*, likelihood, scope, range). It further considers the likelihood that the measure will be effective if implemented (probability of accomplishing the mitigating result if implemented as planned), the likelihood of effective implementation (probability implemented as planned); and

(2) The practicability of the measures for applicant implementation, which may consider such things as cost, impact on operations, and, in the case of a military readiness activity, personnel safety, practicality of implementation, and impact on the effectiveness of the military readiness activity.

To reduce the potential for disturbance to marine mammals caused by acoustic stimuli associated with IHA activities, NSF has proposed to implement mitigation measures for the northern sea otter including, but not limited to, the following:

• Development of marine mammal monitoring and mitigation plans;
• Reduced survey transect lines and daylight-only operations in area of highest sea otter densities;
• Establishment of shutdown and monitoring zones;
• Vessel-based visual mitigation monitoring by Protected Species Observers;
• Site clearing before start-up;
• Soft-start and shutdown procedures.

The specific methods to be implemented are further specified in the Service's draft EA (USFWS 2020) available at: *http://www.regulations.gov*, Docket No. FWS–R1–ES–2020–0131.

Estimated Take by Incidental Harassment of Northern Sea Otters

In a previous section, we discussed the components of the project activities that have the potential to affect sea otters and the physiological and behavioral effects that can be expected. Here, we discuss how the Service characterizes these effects under the MMPA.

An individual sea otter's reaction to human activity will depend on the otter's prior exposure to the activity, its need to be in the particular area, its physiological status, or other intrinsic factors. The location, timing, frequency, intensity, and duration of the encounter are among the external factors that will also influence the animal's response. Intermediate reactions that disrupt biologically significant behaviors are considered Level B harassment under the MMPA. The Service has identified the following sea otter behaviors as indicating possible Level B harassment:

• Swimming away at a fast pace on belly (*i.e.*, porpoising);
• Repeatedly raising the head vertically above the water to get a better view (spy hopping) while apparently agitated or while swimming away;
• In the case of a pup, repeatedly spy hopping while hiding behind and holding onto its mother's head;
• Abandoning prey or feeding area;
• Ceasing to nurse and/or rest (applies to dependent pups);
• Ceasing to rest (applies to independent animals);
• Ceasing to use movement corridors along the shoreline;
• Ceasing mating behaviors;
• Shifting/jostling/agitation in a raft so that the raft disperses;
• Sudden diving of an entire raft; or
• Flushing animals off of a haulout.

This list is not meant to encompass all possible behaviors; other situations may also indicate Level B harassment.

Reactions capable of causing injury are characterized as Level A harassment events. However, it is also important to note that, depending on the duration and severity of the above-described Level B behaviors, such responses could constitute take by Level A harassment. For example, while a single flushing event would likely indicate Level B harassment, repeatedly flushing sea otters from a haulout may constitute Level A harassment.

Calculating Estimate of Takes

In the sections below, we estimate take by harassment of the numbers of sea otters from the Washington stock (in Oregon and Washington) that are likely to be affected during the proposed activities. We assumed all animals exposed to underwater sound levels that meet the acoustic exposure criteria would experience Level A (>232 dB_{RMS}) or Level B (160–232 dB_{RMS}) harassment. To determine the number of otters that may be exposed to these sound levels, we created spatially explicit zones of ensonification using the proposed reduced survey transect lines and determined the number of otters present in the ensonification zones using density information generated from minimum population estimates in Jeffries *et al.* (2019), which subdivides the surveyed area into Cape Flattery to La Push and La Push to north entrance of Grays Harbor. An in-depth explanation of the process used can be found in the Service's draft EA (USFWS 2020) available at: *http://www.regulations.gov*, Docket No. FWS–R1–ES–2020–0131.

The Level A and Level B underwater sound thresholds were used to create spatially explicit ensonification zones surrounding the proposed project transects. We created a buffer with a 46-m (151-ft) width around the proposed project transects to account for the Level A ensonified area on either side of the 24-m-wide (79-ft-wide) airgun array. To determine the Level B ensonified area, we placed a 12,650-m (7.9-mi) buffer around transects in water <100 m (328 ft) deep, and a 9,468-m (5.9-mi) buffer around transects in water 100–1,000 m (328–3,280 ft) deep.

The minimum population estimate from Jeffries *et al.* (2019) can be specifically applied to the surveyed area, which included the Washington coastline between Cape Flattery and Grays Harbor in the nearshore areas less than 25-m (82-ft) depth contour. Sea otters are overwhelmingly observed (95 percent) within the 40-m (131-ft) depth contour (Laidre *et al.* 2009; Tinker *et al.* 2019), thus for the purposes of this analysis, the population estimated by Jeffries *et al.* (2019) is assumed to apply to the 40-m (131-ft) depth contour for the waters between Grays Harbor and Cape Flattery. The minimum abundance estimates from Jeffries *et al.* (2019) were divided north and south of the Quillayute River, thus for this analysis habitat was divided into subregions, Cape Flattery south to Quillayute River (subregion north) and Quillayute River to Grays Harbor (subregion mid). Density estimates for the north and mid subregions were calculated by dividing the population estimate for that subregion (Jeffries *et al.* 2019) by the area from shore to the 40-m (131-ft) depth contour. See Table 1 for projected sea otter abundance and density estimates.

Sea otter abundances outside of the area covered by surveys were inferred/ estimated as follows.

• *North and Mid subregions 40–100-m (131–328-ft) depth contour:* While 95 percent of sea otters are observed within the 40-m (131-ft) depth contour, otters do occur farther off shore (see Pearson 2019 for specific instances off Washington coast), thus lower density otter habitat was delineated between the 40- and 100-m (131- and 328-ft) depth contours. To calculate the density of otters in lower density (40–10-m or 131–328-ft) habitat, we multiplied the density of the adjacent high-density habitat by 0.05.

• *North and Mid subregions >100-m (328-ft) depth contour:* Pearson (2019) observed two sea otters (1 in 2017 and 1 in 2018) in waters >100-m (328-ft) depth contour in the Mid subregion. We do not have a reasonable method for determining the density of otters in the waters this deep and far offshore, thus for the purposes of calculating the number of otters that may be exposed, we assumed 2 otters could be in the waters >100-m (328-ft) depth contour in the Mid subregion.

• *South subregion:* Includes the area from Grays Harbor south to Oregon/ California border. This subregion was further divided into three areas because of the differences in transects and sea otter observations: Grays Harbor to Washington/Oregon border, Northern Oregon, Southern Oregon. There are no systematic surveys conducted south of Grays Harbor, but there are consistent reports of individuals as far south as Cape Blanco, Oregon (unpublished FWS data; Jim Rice, Oregon State University, pers. comm). We do not have data to inform a density estimate for these areas; however, in our best professional judgment we estimated that a minimum of four sea otters may be in the south subregion at the time of the project. Pearson (2019) observed one sea otter in waters >100-m (328-ft) depth contour in the South subregion. We do not have a reasonable method for determining the density of otters in the waters this deep and far offshore, thus for the purposes of calculating the number of otters that may be exposed in the Grays Harbor to WA/OR border, we assumed two sea otters could be at any depth. In Oregon, we assumed one otter in each of the two areas, which could be at any depth.

TABLE 1—ESTIMATED SEA OTTER ABUNDANCE AND DENSITIES FOR THE ANALYSIS AREA

Subregion	High density (<40 m)			Lower density (40–100 m)		
	Abundance estimate	Area (km²)	Density	Abundance estimate	Area (km²)	Density
North	549	456	1.2	27	556	0.05
Mid	2,236	1,434	1.56	112	2,060	0.05
South						4

The area impacted in each subregion and depth contour was multiplied by the estimated otter density to determine the number of otters that would experience Level A and Level B sound levels (Tables 2 and 3). The total number of takes was predicted by estimating the projected days of activity in each subregion and depth contour using the reduced transects supplied by NSF. In several areas, the length and direction of the proposed survey transect lines make it highly unlikely that impacts will occur on only 1 day. In these instances, we estimated the days of disturbance based on the number of passes of the survey transect lines.

The following assumptions were pertinent to our estimate of harassment take (see above for specific rationale):

• No otters will occur >100-m (328-ft) depth contour in North subregion.

• Visual observers will not be able to see sea otters in poor weather conditions and will not be observing at night. When visual observers are not able to effectively observe sea otters, there would be no mitigation (shutdown) applied.

• When visual observers are not able to observe sea otters they could be exposed to harassment that has the potential to injure (Level A) or disturb by causing disruption of behavioral patterns (Level B). For the purposes of this analysis, we applied our best professional judgment and erred on the side of the species, attributing the harassment to Level A. In the areas where a density estimate cannot be used to differentiate the number of otters exposed to Level A or Level B, we attributed the harassment to Level A.

• During the project, only two sea otters will be in the waters offshore of Southwest Washington between Grays Harbor and Washington/Oregon border. These two sea otters may be in waters >100 m (328 ft), thus harassment was assigned at Level A conditions.

• During the project, only two sea otters will be in the waters offshore of Oregon. These two sea otters may be in waters at any depth contour, thus harassment was assigned at Level A conditions.

TABLE 2—ESTIMATED NUMBER OF NORTHERN SEA OTTERS ENSONIFIED BY SOUND LEVELS GREATER THAN 232 dB_{RMS} (LEVEL A) DUE TO THE PROPOSED ACTIVITIES

Take was calculated by multiplying the area ensonified in each subregion by that subregion's sea otter density or specific estimate, then multiplied by the projected days of ensonification]

Subregion	Habitat type	Density (otters/km²)	Area impacted (km²)	Estimated take/day	Projected days of take	Estimated survey total takes
North	High (<40m)	1.2	0	0		0
	Low (40–100 m)	.05	0	0		0
	Offshore (>100 m)	0				0
Mid	High (<40 m)	1.56	0	0		0
	Low (40–100 m)	0.05	0	0		0
	Offshore (>100 m)	2 otters		2	2	4

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TABLE 2—ESTIMATED NUMBER OF NORTHERN SEA OTTERS ENSONIFIED BY SOUND LEVELS GREATER THAN 232 dB_{RMS} (LEVEL A) DUE TO THE PROPOSED ACTIVITIES—Continued

Take was calculated by multiplying the area ensonified in each subregion by that subregion's sea otter density or specific estimate, then multiplied by the projected days of ensonification]

Subregion	Habitat type	Density (otters/km²)	Area impacted (km²)	Estimated take/day	Projected days of take	Estimated survey total takes
Grays Harbor-WA/OR border.		2 otter		2	2	4
N Oregon		1 otter		1	2	2
S Oregon		1 otter		1	3	3
Total				5		13
Estimated Stock Total						2,928
Percentage of Stock						0.44

TABLE 3—ESTIMATED NUMBER OF NORTHERN SEA OTTERS ENSONIFIED BY SOUND LEVELS GREATER THAN 160 dB_{RMS} (LEVEL B) DUE TO THE PROPOSED ACTIVITIES

[Take was calculated by multiplying the area ensonified in each subregion by that subregion's sea otter density or specific estimate, then multiplied by the projected days of ensonification]

Subregion	Habitat type	Density (otters/km²)	Area impacted (km²)	Estimated take/day	Projected days of take	Estimated survey total takes
North	High (<40 m)	1.2	0	0	0	0
	Low (40–100 m)	.05	0	0	1	0
	Low (40–100 m)	.05	0	0	2	0
	Offshore (>00 m)	0				
Mid	High (<40 m)	1.56	0	0		0
	Low (40–100 m)	0.05	0	0	2	0
	Offshore (>100 m)	2 otters	Accounted for in Level A.			
Grays Harbor–WA/OR border		2 otters	Accounted for in Level A.			
N Oregon		1 otter	Accounted for in Level A.			
S Oregon		1 otter	Accounted for in Level A.			
Total				0		0
Estimated Stock Total						2,928
Percentage of Stock						0.00

We expect that up to 13 sea otters may experience Level A and/or Level B take due to harassment by noise (Tables 2 and 3). While sea otters in these areas are most likely to be exposed to Level B harassment, during times when sea otters cannot be observed, we are erring on the side of the species and attributing the potential harassment to Level A, thus the total number of otters harassed is accounted for under Level A. The revised transects provided by NSF resulted in the area of ensonification being beyond the 100-m (328-ft) depth contour for the entire coast of Washington; therefore, no otters in waters less than 100 m (328 ft) deep are anticipated to be harassed by the activities. The total number of incidental takes of sea otters is expected to be less than 13. Take from sources other than noise is not expected.

Findings

The Service proposes the following findings regarding this action:

Small Numbers Determination

The statute and legislative history do not expressly require a specific type of numerical analysis for the small take evaluation, leaving the determination of "small" to the agency's discretion. In this case, we propose a finding that the NSF and L–DEO project may result in incidental take of up to 13 otters from the Washington sea otter stock. This represents less than 1 percent of the stock. Predicted levels of take were determined based on estimated density of sea otters in the project area and an ensonification zone developed using empirical evidence from the same geographic area and corrected for the methodology proposed by NSF and L–DEO for this project. Based on these numbers, we propose a finding that the NSF and L–DEO project will take only a small number of marine mammals.

Negligible Impact

We propose a finding that any incidental take by harassment resulting from the proposed activity cannot be reasonably expected to, and is not reasonably likely to, adversely affect the sea otter through effects on annual rates of recruitment or survival and will, therefore, have no more than a negligible impact on the species or stocks. In making this finding, we considered the best available scientific information, including: (1) The biological and behavioral characteristics of the species; (2) the most recent information on species distribution and abundance within the area of the specified activity; (3) the current and expected future status of the stock (including existing and foreseeable human and natural stressors); (4) the potential sources of disturbance caused by the project; and (5) the potential responses of marine mammals to this disturbance. In addition, we reviewed applicant-provided material, information in our files and datasets, published reference materials, and input from experts on the sea otter.

The Service does not anticipate that mortality of affected otters would occur as a result of NSF and L–DEO's planned survey. Thus, mortality is not authorized. We are proposing to authorize Level A and Level B harassment of 13 sea otters. The effects to these individuals are unknown, and lasting effects to survival and reproduction for these otters are possible. However, we believe that any PTS incurred as a result of the planned activity would be in the form of only a small degree of PTS, not total deafness, and would be unlikely to affect the fitness of any individuals for the following reasons: (1) The constant movement of the *R/V Langseth* means the vessel is not expected to remain in any one area in which individual otters may spend an extended period of time (*i.e.*, since the duration of exposure to loud sounds will be relatively short); and (2) we expect that sea otters would be likely to move away from a sound source that represents an aversive stimulus, especially at levels that would be expected to result in PTS, given sufficient notice of the *R/V Langseth's* approach due to the vessel's relatively low speed when conducting seismic surveys.

We expect that the majority of takes would be in the form of short-term behavioral harassment in the form of temporary avoidance of the area or ceasing/decreased foraging (if such activity were occurring). Reactions to this type of harassment could have significant biological impacts for affected individuals but are not likely to result in measurable changes in their survival or reproduction. The otters subject to short-term behavioral harassment would be the same otters that may be subject to Level A harassment.

The total number of animals affected and severity of impact is not sufficient to change the current population dynamics of the sea otter at the subregion or stock scales. Although the specified activities may result in the take of up to 13 sea otters from the Washington stock, we do not expect this level of harassment to affect annual rates of recruitment or survival or result in adverse effects on the species or stock as all of the projected takes occur outside of the areas used by females and are most likely to be males.

With implementation of the proposed project, sea otter habitat may be impacted by elevated sound levels, but these impacts would be temporary and are not anticipated to result in detrimental impacts to sea otter prey species. Because of the temporary nature of the disturbance, the impacts to sea otters and the food sources they utilize are not expected to cause significant or long-term consequences for individual sea otters or their population.

The proposed mitigation measures are expected to reduce the number and/or severity of take events by allowing for detection of sea otters in the vicinity of the vessel by visual observers, and by minimizing the severity of any potential exposures via shutdowns of the airgun array. These measures, and the monitoring and reporting procedures, are required for the validity of our finding and are a necessary component of the proposed IHA. For these reasons, we propose a finding that the 2021 NSF and L–DEO project will have a negligible impact on sea otters.

Impact on Subsistence

The subsistence provision of the MMPA does not apply to northern sea otters in Washington and Oregon.

Required Determinations

Endangered Species Act

The Service's proposed take authorization has no effect on any species listed as threatened or endangered under the ESA. The proposed NSF Seismic Survey is a Federal action currently undergoing separate interagency consultation with the Service pursuant to the ESA. As ESA-listed species or critical habitat will not be impacted by the Service's proposed take authorization, intra-agency consultation for the permit action is not required.

National Environmental Policy Act

We have prepared a draft EA (USFWS 2020) addressing the proposed MMPA take authorization in accordance with the requirements of NEPA (42 U.S.C. 4321 *et seq.*). Based on the findings presented in the EA, we have preliminarily concluded that approval and issuance of the authorization for the nonlethal, incidental, unintentional take by Level A and Level B harassment of small numbers of the Washington stock of the northern sea otter caused by activities conducted by the applicant would not significantly affect the quality of the human environment, and that the preparation of an environmental impact statement for this action is not required by section 102(2) of NEPA or its implementing regulations. We are accepting comments on the draft EA as described above in **ADDRESSES**.

Government-to-Government Relations With Native American Tribal Governments

In accordance with: The President's memorandum of April 29, 1994, "Government-to-Government Relations with Native American Tribal Governments" (59 FR 22951); the Native American Policy of the Service (January 20, 2016); Executive Order 13175 (November 6, 2000); and the Department of the Interior's manual at 512 DM 2, we readily acknowledge our responsibility to communicate meaningfully with Federally recognized Tribes on a Government-to-Government basis. We have evaluated possible effects of the proposed MMPA take authorization on federally recognized Indian Tribes and have determined that there are no effects.

Proposed Authorization

We propose to issue an IHA to NSF for incidental takes by Level A and Level B harassment of up to 13 sea otters from the Washington stock of the northern sea otter. The final authorization would incorporate the mitigation, monitoring, and reporting measures as described below and fully detailed in the draft EA. The taking of sea otters whenever the required conditions, mitigation, monitoring, and reporting measures are not fully implemented as required by the IHA will be prohibited. Failure to follow these measures may result in the modification, suspension, or revocation of the IHA. Authorized take will be limited to PTS and disruption of behavioral patterns that may be caused by geophysical surveys and support activities conducted by NSF and L–DEO in Washington and Oregon from May 1 to June 30, 2021. We anticipate no take in the form of death of northern sea otters resulting from these surveys.

If take exceeds the level or type identified in the proposed authorization (*e.g.*, greater than 13 incidents of take of sea otters), the IHA will be invalidated and the Service will reevaluate its findings. If project activities cause unauthorized take, the applicant must take the following actions: (i) Cease its activities immediately (or reduce activities to the minimum level necessary to maintain safety); (ii) report the details of the incident to the Service's Washington Fish and Wildlife Office within 48 hours; and (iii) suspend further activities until the Service has reviewed the circumstances, determined whether additional mitigation measures are necessary to avoid further unauthorized taking, and notified the applicant that they may resume project activities.

All operations managers and vessel operators must possess a copy of the IHA and maintain access to it for reference at all times during project work. These personnel must understand, be fully aware of, and be capable of implementing the conditions of the IHA at all times during project work.

The IHA will apply to activities associated with the proposed project as described in this document, the draft EA, and in the applicant's amended application and environmental assessments. Changes to the proposed project without prior Service authorization may invalidate the IHA.

Operators shall allow Service personnel or the Service's designated representative to visit project work sites to monitor impacts to sea otters at any time throughout project activities so long as it is safe to do so. "Operators" are all personnel operating under the applicant's authority, including all contractors and subcontractors.

A final report will be submitted by NSF to the Service within 90 days after completion of work or expiration of the IHA. The report will describe the operations that were conducted and document sightings of sea otters near the operations. The report will provide full documentation of methods, results, and interpretation pertaining to all monitoring, including factors influencing visibility and detectability of sea otters. The final report will summarize the dates and locations of seismic operations, and all northern sea otter sightings (dates, times, locations, activities, associated seismic survey activities). The report will also include estimates of the number and nature of exposures, if any, that occurred above the harassment threshold based on Protected Species Observer (PSO) observations and including an estimate of those that were not detected.

The report shall also include geo-referenced time-stamped vessel transect lines for all time periods during which airguns were operating. Transect lines should include points recording any change in airgun status (*e.g.*, when the airguns began operating, when they were turned off, or when they changed from a full array to a single gun or vice versa). GIS files shall be provided in ESRI shapefile format and include the UTC date and time, latitude in decimal degrees, and longitude in decimal degrees. All coordinates shall be referenced to the GCS_North_American_1983 geographic coordinate system. In addition to the report, all raw observational data shall be made available to the Service. The report will be accompanied by a certification from the lead PSO as to the accuracy of the report, and the lead PSO may submit directly to the Service a statement concerning implementation and effectiveness of the required mitigation and monitoring.

References

A list of the references cited in this notice is available at *www.regulations.gov* in Docket No. FWS–R1–ES–2020–0131.

Request for Public Comments

If you wish to comment on this proposed authorization or the associated draft EA, or both, you may submit your comments by any of the methods described in **ADDRESSES**. Please identify if you are commenting on the proposed IHA, draft EA, or both. Please make your comments as specific as possible, confine them to issues pertinent to the proposed authorization, and explain the reason for any changes you recommend. Where possible, your comments should reference the specific section or paragraph that you are addressing. The Service will consider all comments that are received before the close of the comment period (see **DATES** above).

Before including your address, phone number, email address, or other personal identifying information in your comment, you should be aware that your entire comment—including your personal identifying information—may be made publicly available at any time. While you can ask us in your comment to withhold your personal identifying information from public review, we cannot guarantee that we will be able to do so.

Dated: February 23, 2021.

Hugh Morrison,

Deputy Regional Director, Interior Regions 9 and 12.

[FR Doc. 2021–04081 Filed 2–26–21; 8:45 am]

BILLING CODE 4333–15–P

INTERNATIONAL TRADE COMMISSION

[Investigation No. 337–TA–1236]

Certain Polycrystalline Diamond Compacts and Articles Containing Same; Notice of Commission Determination Not To Review an Initial Determination Amending the Complaint and Notice of Investigation

AGENCY: U.S. International Trade Commission.

ACTION: Notice.

SUMMARY: Notice is hereby given that the U.S. International Trade Commission ("Commission") has determined not to review an initial determination ("ID") (Order No. 8) of the presiding administrative law judge ("ALJ") granting an unopposed motion of complainant US Synthetic Corporation for leave to amend the complaint and notice of investigation to substitute Guangdong Juxin New Materials Technology Co., Ltd.as a respondent in place of Zhuhai Juxin Technology.

FOR FURTHER INFORMATION CONTACT: Ronald A. Traud, Esq., Office of the General Counsel, U.S. International Trade Commission, 500 E Street SW, Washington, DC 20436, telephone (202) 205–3427. Copies of non-confidential documents filed in connection with this investigation may be viewed on the Commission's electronic docket (EDIS) at *https://edis.usitc.gov*. For help accessing EDIS, please email *EDIS3Help@usitc.gov*. General information concerning the Commission may also be obtained by accessing its internet server at *https://www.usitc.gov*. Hearing-impaired persons are advised that information on this matter can be obtained by contacting the Commission's TDD terminal on (202) 205–1810.

SUPPLEMENTARY INFORMATION: The Commission instituted this investigation on December 29, 2020, based on a complaint filed by US Synthetic Corporation of Orem, Utah ("US Synthetic"). 85 FR 85661 (Dec. 29, 2020). The complaint alleges violations of section 337 of the Tariff Act of 1930, as amended, 19 U.S.C. 1337 ("section 337"), based upon the importation into the United States, the sale for importation, and the sale within the United States after importation of certain polycrystalline diamond compacts and articles containing same by reason of infringement of certain claims of U.S. Patent Nos. 9,932,274; 10,508,502; 9,315,881; 10,507,565; and 8,616,306. *Id.* The complaint further

APPENDIX E: NSF NEPA DRAFT EA COMMENTS AND RESPONSES

Appendix E: NSF NEPA Draft EA Comments and Responses

Commenter	**Comment**	**Response**
Marlene P		

	First and foremost is the potential impact on the endangered Southern Resident Killer Whale population along the Vancouver Island BC and Washington State coasts. Your Figure 1 map of the proposed survey sites has this critical habitat area marked, but there are survey transects and receiver locations in that area anyway. This population is down to 72 whales. The three main impacts on them are food sources, pollution, and vessel noise, and yet you are proposing activities that meet, or possibly exceed, Level B harassment takings. This is unacceptable. You cannot put this severely endangered population in harm's way, even for "short-term, localized changes in behavior." You state you will monitor for marine mammals and will "power down" or even shut down in their presence. This is a Resident population. Whether you see them, hear them, or not, they are always there. No surveying should be done within their critical habitat area.	Thank you for your comment. We worked closely with NMFS to ensure that operations would minimize any potential impacts to Southern Resident Killer Whale (SRKW) and their critical habitat (CH). During consultation with NMFS per the ESA and MMPA, additional monitoring and mitigation measures to operate safely and minimize impacts to SRKW were considered and proposed survey tracklines were revised. These changes and additional measures include:
		- elimination of survey tracklines in US & Canadian designated SRKW CH;
		- elimination of survey tracklines in water depths <100 m off WA and Canada;
		- north of Tillamook Head, OR, including within the Canadian EEZ, in water depths between 100-200 m:
		    - daylight only operations;
		    - additional PSOs monitoring from a support vessel operating 5 km in front of R/V *Langseth*
		- shutdowns for SRKW at any distance visually observed or detected acoustically.

	In general, regarding marine mammals, you state you will visually monitor for their presence in daytime and acoustically monitor them during nighttime testing, requiring 30 minutes of absence before doing a start-up. Nighttime operations are too likely to miss the presence of marine mammals and turtles. At the time of year you are proposing for this study, you will have 15-16 hours of daylight each day. Please consider shutting down at night.	NSF took into consideration this suggestion. Shutting down during all nighttime operations would significantly prolong the survey effort within the survey area. PSOs would be on watch during daytime to ensure the exclusion zone around the source is free of animals when the source is ramped up. Once airguns are operational, it is not anticipated that animals would move towards the source if they were experiencing harassment effects. Given specific concerns about SRKW, however, operations would be conducted during daylight only in areas north of Tillamook Head, OR, including within the Canadian EEZ, in water depths between 100-200 m. In addition, operations proposed for occurring in anticipated highest density areas for SRKW were eliminated from the survey design, including in almost all waters <100 m deep.
	Is anyone monitoring the coastlines to be sure there are not any marine mammals, sea turtles, marine birds, or fish washing ashore? If this occurs, you should immediately shut down your operations in that area.	Although strandings are not anticipated from the proposed activities, there is an active stranding network in the survey area. In the event of any stranding resulting from the Proposed Action, operations would be immediately halted. Additionally, in the event of any live stranding (or near-shore atypical milling) event within 50 km of the survey operations not a result of LDEO activities, LDEO would be advised of the need to implement shutdown procedures for all active acoustic sources operating within 50 km of the stranding.
	You state your operations will comply with all international, federal, and state laws and regulations. On your list of laws and agencies, I do not see the Ocean Resources Management Act (ORMA) of Washington state: RCW. 43.143. You need to be sure your operations comply with this law.	Thank you for highlighting this requirement. NSF addressed compliance with ORMA as part of its compliance with the Coastal Zone Management Act.

Oregon Dept of Fish and Wildlife (ODFW)		
	Recommendation: The EA should directly address the enhanced risk to gray whales presented by the survey's cruise plan relative to Oregon's coastline.	ODFW noted particular concern about "...gray whales during their "Phase B" migration between April 1 and June 15, when mothers and calves are moving north through very shallow waters (generally within 800 m of shore) (Herzing and Mate 1984, Adams et al 2014)." There may be some overlap with survey operations and the end of the gray whale migration period off Oregon; however, all seismic lines would be >9.5 km from shore. To reduce potential impacts to migrating gray whale mother-calf pairs, the acoustic source would be shut down at any distance. In addition, survey operations in shallow waters, <100 m, were mostly eliminated off the coast of Oregon.
	Recommendation: We request that NSF provide ODFW with data after the cruise documenting the cruise track, ensonification levels, and Marine Mammal Observer data regarding all marine mammal encounters, to allow us to account for potential effects of the survey on our ongoing study.	Once completed, the protected species observer (PSO) report prepared for the seismic survey, which would include the information requested, would be made publicly available on the NSF website. NSF can provide ODFW a copy of the report as well.
	Recommendation: NSF should pursue the implementation of the analytical approach offered by Crone et al, in applying a streamer-based assessment of the ensonified area. These data should be provided to ODFW after the survey to allow assessment of the potentially affected areas and the development of future mitigation approaches.	Thank you for this suggestion. NSF has taken this recommendation under consideration. Unfortunately, it is not feasible in current circumstances to undertake an acoustic radiation study using a moored hydrophone array to better resolve the three-dimensional acoustic field generated by a seismic source in shallow water. NSF would, however, discuss with Crone et al the possibility of analyzing streamer data. At the present time, NSF does not have any research proposals to survey in the area in the foreseeable future. Survey data would be made available to the public, including ODFW, consistent with NSF's Data Policy.

	Recommendation: Furthermore, NSF should direct some level of project funding associated with conducting marine acoustic surveys toward improving the assessment of shallow-water ensonification levels, as these surveys are repeated events and the need to accurately assess and mitigate shallow-water impacts is likely to grow.	Thank you for the suggestion. NSF has taken this recommendation under advisement.
	Recommendation: The EA should rigorously address the potential for impacts to seafloor associated fish and invertebrates, including commercially important crustaceans and mollusks. One way it could do this would be by providing a table of total seafloor area expected to be ensonified at various intensities by depth stratum and substrate type. This would be analogous to the way total mitigation zone coverage is provided for marine mammals, but calculated for the acoustic energy arriving at the seafloor.	The potential impacts on fish and invertebrates are discussed in Section 4.1.2; however, as noted there, many data gaps remain regarding the potential effects of seismic on fish and invertebrates. Total area expected to be ensonified by water depth is provided in Appendix B. NSF and Bureau of Ocean Energy Management (BOEM) have co-funded a research proposal focused on (1) measuring particle motion and pressure from the seismic survey and (2) behavioral responses of important marine species: rockfishes (*Sebastes* spp.), Dungeness crab, and longnose skate. The study, to be carried out by researchers from Oregon State University, would occur concurrently with the seismic survey.
	Recommendation: Furthermore, NSF should direct some level of project funding associated with conducting marine acoustic surveys toward improving the understanding of impacts on fish and invertebrates in coastal waters. This research should include not only direct effects of high SPL, but also particle motion, which multiple researchers have identified as a likely important mechanism of effect on fish and invertebrates (Hawkins and Popper 2017), especially in shallow water.	NSF has funded research activities and scientific conferences related to improving the understanding the impacts of sound on marine species, including fish. In addition, NSF staff participate in interagency committees focused on making advances on this topic. NSF and Bureau of Ocean Energy Management (BOEM) have co-funded a research proposal focused on (1) measuring particle motion and pressure from the seismic survey and (2) behavioral responses of important marine species: rockfishes (*Sebastes* spp.), Dungeness crab, and longnose skate. The study, to be carried out by researchers from Oregon State University, would occur concurrently with the seismic survey.

	Recommendation: NSF should resolve potential space use conflicts through communication lines already established (e.g. Oregon Sea Grant), modify its OBN deployment plan as necessary to avoid equipment loss, and act early and comprehensively to communicate the location of all OBSs and OBNs, as well as the anticipated dates/times of transit for each transect line. This communication responsibility extends to other ocean users, such as recreational or commercial SCUBA divers (e.g. red urchin harvesters).	NSF has supported research activities in this region previously and has successfully managed space-use conflicts. While NSF anticipates limited space-use conflict with the fishing industry, the action proponents planned outreach efforts and coordinated with members of the fishing industry in advance of the proposed activities to help further reduce any potential space-use conflicts. For example, the PIs coordinated with and engaged with the commercial fishing community through participating in and presenting information at meetings such as the Oregon Fishermen's Cable Committee (OFCC) and the Scientists and Fishermen Exchange (SAFE) Program through Oregon Sea Grant. The researchers prepared and plan to distribute digital maps of the proposed tracklines and OBS/OBN deployments to the fishing community to avoid conflicts. During operations, the vessels would communicate with other ocean users via Notice to Mariners and direct radio communications from the vessel. In addition, the vessel operators would notify identified Coastal Treaty Tribe points of contact 3 days in advance of entering Usual and Accustomed fishery areas.
	Recommendation: NSF should include in its EA an assessment of the predicted SEL (accumulated sound exposure level) for each of the Marine Reserves. We request that NSF provide ODFW with data after the cruise documenting the cruise track, ensonification levels, and SEL (modeled based on actual cruise data) for each of the Marine Reserves, to allow ODFW to interpret any potential seismic survey impacts observed by ODFW in the Reserves.	Survey data would be made available to the public, including ODFW, consistent with NSF's Data Policy. Once completed, NSF can provide to ODFW the PSO report prepared for the seismic survey, which would include the actual survey tracklines.
	Recommendation: The EA should explicitly assess the risk of mortality for any fish or invertebrates in the Marine Reserves. If mortality risks are identified, the cruise plan should be modified to provide a sufficient spatial buffer to insure compliance with the no-take provisions.	Mortality of fish and invertebrates in the Marine Reserves are not anticipated. Section 4.1.2 and 4.1.4 of the Draft EA focused on direct and indirect impacts on fish. The Draft EA noted that any injurious impacts on fish would only occur within a few meters of the airguns. All Marine Reserves are located at least 2 km from the seismic source.

Center for Biological Diversity		
	As a preliminary matter, we ask for an extension of the public comment period for this draft EA. We just received notice of its existence and it has wide-ranging implications for many marine species, including several listed as threatened and endangered under the Endangered Species Act.	The Draft EA was posted on the NSF website for a 30-day public comment period (Feb 7 thru Mar 7, 2020). CBD has commented on NSF activities in the past and is aware that NSF posts Draft EAs on its website for public comment. No other requests for an extension of the public comment period were received. For these reasons, an extension of the public comment period was determined to be unwarranted and NSF did not extend the public comment period.
	This EA does not use best available science for several species, including for Southern Resident killer whales (SRKW). There is an abundance of new data on the status and seasonal distribution of SRKW, threats to SRKW, and specifically the impacts of noise and cumulative impacts on SRKW that are omitted from discussion.	NSF disagrees that the best available science was not used for the species analyzed in the Draft EA. NSF used data sources for abundance and distribution recommended in consultation with NMFS under the MMPA and ESA. In addition, NSF's contractors broadly reviewed published literature to prepare the Draft EA, and no recent literature on the effects of seismic sound on killer whales has been published. NSF has taken into consideration the recent publications noted by CBD; however, these do not change the outcome of the effects assessment. Other new papers on the effects of vessel noise on SRKW published after the Draft EA was issued have been taken into consideration in this Final EA.
	The 2011 PEIS and the EA for similar surveys conducted in June–July 2012 upon which this draft EA relies are woefully outdated.	The 2011 PEIS provides a significant amount of information that is germane to the conduct of marine seismic research, including how they are typically conducted, descriptions of equipment and vessels, potential impacts, etc. In addition to the PEIS, NSF prepared a site-specific Draft EA for the Proposed Action, which tiers to the PEIS and an EA prepared in 2012 for a similar seismic survey conducted in the proposed survey area. The Draft EA includes information from publications issued since the issuance of PEIS in 2011 and the 2012 EA. Therefore, NSF disagrees with CBD's conclusion that the documentation is outdated.
	This EA must separately and thoroughly examine the impacts of this project on the endangered SRKW. It is unacceptable to lump them in with all other stocks of killer whales and imply that as a whole they are abundant across the globe, while	Although Southern Resident Killer Whales (SRKW) were discussed along with other killer whales in the Draft EA, Section 3.3.2.15, estimated takes for killer whales were considered proportionally for SRKW (Table 8, footnote #9). NMFS also parsed takes for SRKW in their analysis conducted under the MMPA and ESA (Appendix C).

	disregarding the fact that this highly imperiled distinct population segment is down to just 72 animals.	The SRKW population size was noted in Table 5. Southern Resident Killer Whale Critical Habitat was discussed in the Draft EA, Section 3.2.1.
	This EA insufficiently considers the impacts of this project on SRKW and its designated and proposed expanded critical habitat (see attached Center for Biological Diversity comments on the proposed expansion rule). The EA does not describe the overlap of the transect lines to the proposed expanded critical habitat or the received noise levels within designated and proposed critical habitat. It also ignores new data on coastal distribution and abundance.	Southern Resident Killer Whale Critical Habitat (SRKW CH), and the proposed expansion currently proposed by NMFS, was discussed in the Draft EA, Section 3.2.1. Although the proposed SRKW CH is not yet in effect, NSF was aware of the sensitivities associated with SRKW and took that into consideration during the survey design. Further NSF consulted with NMFS on the Proposed Action per the MMPA and ESA, and NMFS took the proposed SRKW CH into consideration when evaluating the project. The Draft EA assessed the potential impacts of the Proposed Action in the entire survey area and therefore covered the area under consideration by NMFS' proposed expansion of the SRKW critical habitat. No survey transects are planned in existing critical habitat in the U.S. or Canada, and critical habitat would not be ensonified to levels >160 dB. However, some survey transects are expected to enter proposed critical habitat. NSF has taken into consideration the recent publications noted by CBD; however, this does not change the outcome of the effects assessment.
	We urge you to include more information about the impacts of this project on SRKW and SRKW critical habitat in Canada. The EA only notes that two of the survey transects go right through critical habitat for SRKWs (Swiftsure Bank and La Perouse Bank). This is a potentially significant impact given that SRKWs are spending less time inshore and more time in those areas. This project and this species (and threats to its continued existence) are transboundary and must be assessed as such in a coordinated fashion. To conclude “most sightings within the critical habitat off southwestern Vancouver Island have occurred closer to shore than the proposed seismic transects” is not sufficient.	Thank you for noting these concerns. The proposed survey lines (and any potential Level B ensonified area) within SRKW CH designated by Canada were eliminated from the Proposed Action. NSF used SRKW data sources recommended in consultation with NMFS under the MMPA and ESA. In addition, NSF's contractors broadly reviewed published literature to prepare the Draft EA. LDEO submitted a Request for Review pursuant to the Canadian Fisheries Act to the Department of Fisheries and Oceans Canada for species under their jurisdiction and will comply with the requirements issued when operating within the Canadian EEZ.

	The EA must describe expected received noise levels for SRKW and other species and their critical habitat with specificity.	Potential effects of the Proposed Action are described in Chapter IV of the Draft EA, which included analysis of impacts from received noise levels based on predicted sound propagation also described in Chapter II. In addition, during consultation with NMFS per the MMPA and ESA, NSF analyzed empirical data from a similar survey conducted in 2012 in or near the proposed survey area. Based on this analysis source propagation distances were updated and revised in the Final EA (See Section 2.1.3.1, Table 1 and 2; and, Appendix A).
	The EA does not describe or defend its Level A and Level B estimates sufficiently in Table B-2 and its appendices. For example how did it arrive at the footnote for killer whales committing to only taking 8 SRKW by Level B harassment? How does it assume only 4 leatherback sea turtles taken by Level B harassment?	The methods for determining Level A and Level B are detailed in Section 4.1.1.5 of the EA and followed the guidelines set forth by NMFS. The number of takes were calculated based on the expected density of a species and the area expected to be ensonified. The methods used by NSF to determine the number of takes for various stocks of killer whales, including SRKW, are described in Appendix B. The methods used by NMFS are described in Appendix C.
	The EA must analyze alternate times for conducting this survey and other mitigation measures and alternatives to avoid and minimize impacts to SRKW and other species. It must take into account their seasonal distribution and essential behaviors.	During seismic surveys, factors such as Beaufort sea state can impact the quality of data collected. The proposed survey timeframe is optimized as operations would occur during a timeframe when sea state conditions are generally best for seismic survey data collection. Collecting low quality data would not meet the Purpose and Need of the Proposed Action and would result in the need for re-surveying the area. Therefore, conducting the survey at alternative times is not a viable Action Alternative for the Proposed Action. NSF did consult with NMFS and FWS per the ESA and MMPA to consider ways to reduce any potential impacts to SRKW and other species, including taking into consideration seasonal distribution and behaviors. Additional monitoring and mitigation measures were taken into consideration. Final monitoring and mitigation measures that would be followed (including measures adjusted or added beyond those originally proposed) are noted in Section 2.1.3.

	The EA must actually describe the direct, indirect, and cumulative impacts of this project on the impacted marine species. It describes the project, it describes the species, but it fails to connect the two with any meaningful analysis. For example, the EA notes the survey will take 4 leatherback sea turtles and be conducted within its designated critical habitat where they “could be encountered” and would likely be “adversely affected.” That is the extent of the EA’s inquiry for this highly endangered species. This cursory analysis is not the “hard look” required by the National Environmental Policy Act.	The Draft EA also tiers to the PEIS which describes potential impacts from marine geophysical research on sea turtles in section 3.4.1. General distribution of sea turtles off B.C. and just south of the survey area off California are discussed in Sections 3.4.3.2 and 3.4.2.3 of the PEIS, respectively. The Draft EA also tiers to the 2012 EA. We believe direct, indirect, and cumulative impacts from the Proposed Action are thoroughly considered when taking the Draft EA, the 2012 EA, and the PEIS into consideration.

APPENDIX F: USFWS ESA LOC & BIOLOGICAL OPINION

United States Department of the Interior

FISH AND WILDLIFE SERVICE
911 NE 11th Avenue
Portland, Oregon 97232-4181

In Reply Refer to:
FWS/R109/R112/AES/
01E00000-2020-I-0001

JAN 1 1 2020

Ms. Holly E. Smith
National Science Foundation
2415 Eisenhower Avenue
Alexandria, Virginia 22314

Dear Ms. Smith:

This responds to your November 22, 2019, letter and Biological Evaluation (BE) requesting informal consultation with the U.S. Fish and Wildlife Service (Service) under section 7 of the Endangered Species Act (ESA), as amended. At issue are the effects of the National Science Foundation's (NSF) funding of proposed high-energy (seismic) marine geophysical surveys on the endangered short-tailed albatross (*Phoebastria albatrus*), endangered Hawaiian petrel (*Pterodroma sandwichensis*), and the threatened marbled murrelet (*Brachyramphus marmoratus*). The proposed surveys, consisting of 6890 km of transect lines covered across 37 days of seismic operation, will occur in the late spring and summer of 2020. The purpose of the surveys is to acquire a regional grid of modern marine seismic reflection data spanning the entire Cascadia Subduction Zone of Northeast Pacific Ocean. The proposed seismic surveys will be conducted from the research vessel (R/V) *Marcus G. Langseth* (*Langseth*), which is owned by NSF and operated by Columbia University's Lamont-Doherty Earth Observatory (L-DEO). Monitoring and mitigation measures described in the BE as part of the proposed action are intended to avoid or minimize impacts from vessel interactions and sound.

Your letter requested Service concurrence with your determination that the proposed action may affect, but is not likely to adversely affect, the above listed species which could be present as seasonal visitors to the project area (albatross and petrel) or forage and loaf on waters in the action area adjacent to suitable inland nesting habitat (murrelet). Critical habitat for the marbled murrelet occurs adjacent to the study area, but this habitat is strictly terrestrial and would not be affected by the proposed activities.

Based on the proposed action, species information, and analysis presented in the BE, which is herein incorporated by reference, and other information in our files, we concur with the NSF's determination that implementation of the proposed seismic surveys may effect, but is not likely to adversely affect the short-tailed albatross and the Hawaiian petrel; we do not concur with your determination that the proposed action may effect, but is not likely to adversely affect, the marbled murrelet. For the reasons discussed below, we recommend that the NSF supplement the effects analysis in the BE so that we can further understand your proposed action and how it affects marbled murrelet.

The BE indicates marbled murrelets are unlikely to occur in the offshore waters of the proposed study area; however, they can be expected on survey transects that approach within a few kilometers from shore. We are unable to determine whether the exposure of marbled murrelets to the stressors caused by

INTERIOR REGION 9
COLUMBIA–PACIFIC NORTHWEST
IDAHO, MONTANA*, OREGON*, WASHINGTON
*PARTIAL

INTERIOR REGION 12
PACIFIC ISLANDS
AMERICAN SAMOA, GUAM, HAWAII, NORTHERN MARIANA ISLANDS

the proposed action are significant or discountable. Murrelets may be difficult to detect on the open ocean at any time, but particularly in low light conditions and at night. This would limit the effectiveness of proposed monitoring and mitigation measures. Whether exposure leads to adverse effects is difficult to determine without some additional analysis. We are requesting the NSF to prepare a supplemental analysis to improve the understanding of how the action may affect the marbled murrelet.

This analysis should include an evaluation of diving murrelet exposure and response to each of the various sound-producing devices and sonar types that are part of the proposed action. The analysis should address potentially injurious exposures by evaluating the exposures in SEL and dBpeak, and potential behavioral disruption by assessing exposure in dBrms, which provides a measure of the total sound pressure level produced by an impulsive source. SEL is a measure of sound exposure level, and dBpeak values are used to define the peak pressure level at which injury may occur (i.e., physical damage to body tissues caused by a sharp pressure gradient between a gas or fluid-filled space inside the body and the surrounding gas or liquid).

The Service has used both dBpeak (for injury) and dBrms (for behavioral effects) threshold values to evaluate adverse injury and disturbance effects on diving seabirds. The supplemental analysis should also address the duration, severity, location, timing and the cumulative effects of exposures on the murrelet. Lack of existing audiograms or thresholds established for seabirds is not a sufficient basis for determining whether adverse effects are likely to result from exposure. Barring any specific data on seabirds, we recommend a surrogate approach using existing data for other wildlife species subject to similar exposures.

This letter concludes informal consultation on the effects of the proposed action on the short-tailed albatross and the Hawaii petrel. As provided in 50 CFR §402.16, reinitiation of consultation is required if: (1) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (2) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not previously considered; or (3) a new species is listed or critical habitat designated that may be affected by the identified action. Please note that the Service is currently conducting a status review in response to a substantial listing petition for the tufted puffin (*Fratercula cirrhata*), which was also mentioned in your request. The puffin is listed as endangered by the State of Washington and could be present in the survey area during the survey period along with a number of migratory birds not listed under the ESA. We recommend applying the proposed conservation and mitigation measures described in the BE to the tufted puffin.

We appreciate your concern and efforts to address the conservation of fish and wildlife. If you have any questions regarding this response, please contact Daniel Brown, Fish and Wildlife Biologist, of this office at 503-231-6281 (tel) or at daniel brown@fws.gov (email).

Sincerely,

Assistant Regional Director

Endangered Species Act - Section 7 Consultation

Biological Opinion

addressing the

2021 West Coast Seismic Survey

conducted by the

National Science Foundation

U.S. Fish and Wildlife Service Reference Number:
01E00000-2020-F-0001

Action Agency:	National Science Foundation
Prepared by:	U.S. Fish and Wildlife Service Interior Regions 9 and 12 - Columbia-Pacific Northwest

Digitally signed by MARJORIE NELSON
Date: 2021.04.12 16:32:25 -06'00'

April 12, 2021

Marjorie Nelson, Acting Assistant Regional Director
Ecological Services
Interior Regions 9 and 12

April 2021

TABLE OF CONTENTS

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LIST OF ACRONYMS

2-D	two-dimensional
ADCP	Acoustic Doppler Current Profiler
dB	decibel
EZ	Exclusion Zone
FM	Frequency Modulated
GoM	Gulf of Mexico
Hz	Hertz
kHz	kilohertz
kts	knots
L-DEO	Lamont-Doherty Earth Observatory
MBES	Multibeam Echosounder
MCS	Multi-Channel Seismic
nmi	nautical mile
NSF	National Science Foundation
OBN	Ocean Bottom Node
PTS	Permanent Threshold Shift
PSO	Protected Species Observer
rms	root-mean-square
ROV	remotely operated vehicle
R/V	research vessel
SBP	Sub-bottom Profiler
SEL	Sound Exposure Level (acoustic energy)
SPL	Sound Pressure Level
TS	Threshold Shift
TTS	Temporary Threshold Shift
µPa	microPascal

INTRODUCTION

This document transmits the U.S. Fish and Wildlife Service's (USFWS or Service) biological opinion (BiOp or opinion) addressing the consequences of National Science Foundation (NSF) funding of proposed high-energy (seismic) marine geophysical surveys on the threatened marbled murrelet (*Brachyramphus marmoratus*). Critical habitat for the marbled murrelet occurs adjacent to the study area, but this habitat is strictly terrestrial and is not likely to be affected by the proposed activities. In addition, due to changes in the proposed action that occurred subsequent to initiation of formal consultation, we have determined that the proposed action may affect, but is not likely to adversely affect, the threatened bull trout (*Salvelinus confluentus*) and its designated critical habitat; see Appendix A for the analysis supporting these determinations. This opinion was prepared in accordance with the requirements of section 7 of the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 et seq.). Your request for consultation was received on November 22, 2019.

Consultation History

On November 22, 2019, we received a request for consultation from NSF on their proposed funding of a marine geophysical survey by the R/V *Marcus G. Langseth* (R/V *Langseth* or *Langseth*) of the Cascadia Subduction Zone in the Northeast Pacific Ocean during late spring/summer of 2020.

On December 4, 2019, per our request, we received an observation report from NSF on a prior marine geophysical survey conducted by the R/V *Langseth* of the Axial Seamount.

On January 9, 2020, NSF provided clarification on proposed vessel operations, lighting, and an associated observer program to assist in documenting potential seabird interactions with the vessels associated with the project.

On February 19, 2020, an interagency teleconference was convened to discuss and clarify aspects of the proposed action and to identify information needs for completing the consultation.

On March 13, 2020, the Service received additional analyses regarding the potential exposure of marbled murrelets to underwater sound caused by the proposed project.

On April 6, 2020, the Service requested a revised proposed action description to account for the various measures incorporated to address the sea otter (*Enhydra lutris kenyoni*) and NMFS jurisdictional species.

On June 5, 2020, the Service received information from NSF indicating the proposed action was being delayed until the spring/summer of 2021. At that time, the NSF requested the Service to continue working to complete the consultation as soon as possible.

On June 12, 2020, the Service received additional information from NSF regarding project-caused underwater sound levels and a revised track line map.

On February 26, 2021, the Service met with NSF to discuss a completion date for the biological opinion. At that time, the Service committed to NSF that we would endeavor to complete this opinion by April 20, 2021.

On March 10 and 11, 2021, the Service received responses to our request for NSF review of the draft proposed action description prepared for this biological opinion. The NSF responses contained a number of suggested edits and clarifications.

On March 16, 2021, the Service received NSF revisions to their March 13, 2020, effects analysis for the marbled murrelet due to NSF changes in the proposed action.

BIOLOGICAL OPINION

Description of the Proposed Action

The proposed activities will be conducted in the spring and summer of 2021. Surveys are expected to include approximately 37 days of seismic operations, 2 days of equipment deployment/retrieval, and 1 day of transit. Surveys are proposed to occur within the EEZ of the U.S. and Canada, ranging in water depths from 60 to 4,400 m located at ~42-51° N, ~124-130° W. The surveys include several strike lines, parallel (including one continuous line along the continental shelf) and perpendicular to the coast. The margin perpendicular lines would extend approximately 50 km seaward of the deformation front and landward of the deformation front to as close to the shoreline as authorized. Most of the survey (69 percent) would occur in deep water (>1000 m), 28 percent would occur in intermediate water (100–1000 m deep), and 3 percent would take place in shallow water <100 m deep. Representative survey tracklines are shown in Figure 1 and Figure 2.

7

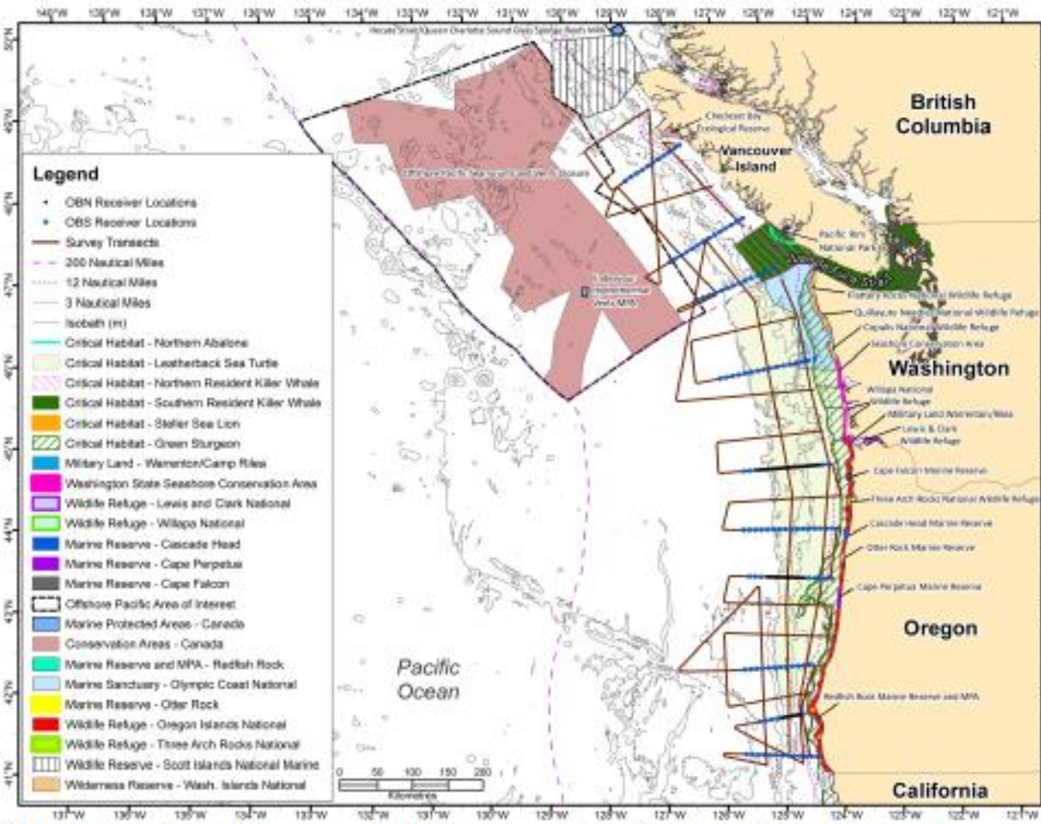

Figure 1. Location of the proposed seismic surveys in the Northeast Pacific Ocean and conservation areas near the proposed survey location (NSF 2019, pg. 3, as updated 5.14.20).

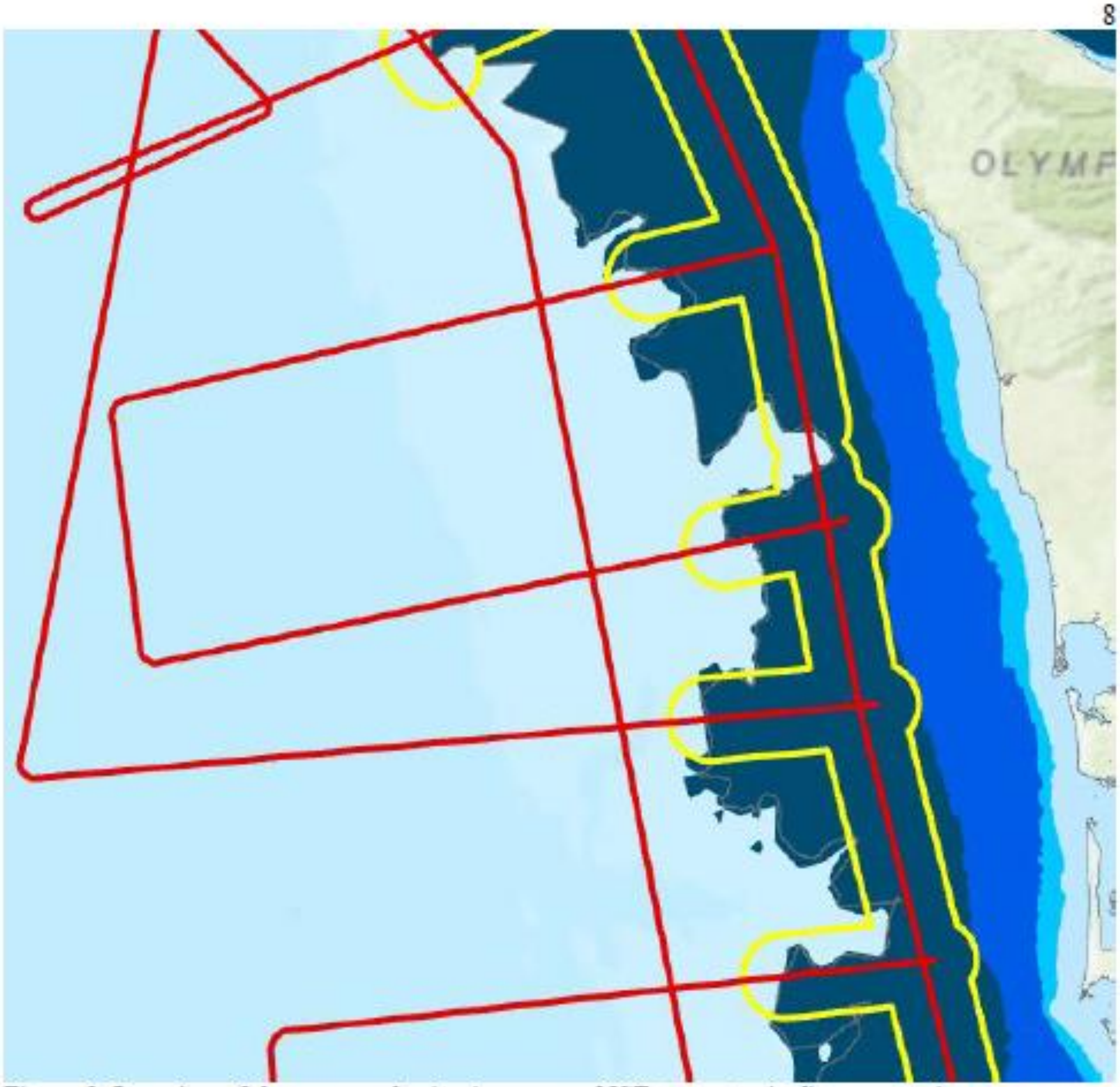

Figure 2. Location of the proposed seismic survey. NSF transects (red) conservation areas (yellow buffers at 9.5 km and 12.5 km) around portions of the transects that are in waters less than 1000 m deep. The blue depth contours are 25, 40, 100, and 1000 m near the proposed survey location (NSF 2019, pg. 3, as updated 5.14.20).

Some deviation in actual track lines, including the order of survey operations, may be necessary for reasons such as poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. For these reasons, the track lines could occur anywhere within the coordinates noted above. A maximum of 6,540 km of transect lines would be surveyed. Approximately 3.6 percent of the transect lines (234 km) would be located in Canadian territorial waters.

The surveys involve one source vessel, R/V *Langseth*, which is owned by the NSF and operated on its behalf by the Lamont-Doherty Earth Observatory (L-DEO), that would leave and return to port in Astoria, Oregon. The R/V *Langseth* would deploy an array of 36 airguns as an energy source with a total volume of approximately 6,600 in^3 at a depth of 12 meters and a shot interval of 37.5

m. The 36-airgun array could operate 24 hours a day, except during mitigation shutdowns, for the entirety of the 37 days of survey. The vessel speed during seismic operations would be approximately 4.2 knots (~7.8 km/hour) during the survey. The receiving system would consist of one 15-kilometer (km) long hydrophone streamer, OBSs, and OBNs. The R/V *Oceanus*, which is owned by NSF and operated by Oregon State University, would be used to deploy the OBSs and OBNs. The R/V *Oceanus* would leave and return to port in Newport, Oregon. As the airguns are towed along the survey lines, the hydrophone streamer would transfer the data to an on-board processing system, and the OBSs and OBNs would receive and store the returning acoustic signals internally for later analysis.

Approximately 17 days prior to the seismic survey, the R/V *Oceanus* would deploy short-period multi-component OBSs and a large-N array of OBNs to record shots along approximately 10 margin-perpendicular profiles. OBSs would be deployed within the proposed survey area between 5 nm and 100 nm from the coast, and at a 10-km spacing along approximately 10 profiles from Vancouver Island to Oregon in water depths ranging from 60 to 3,100 m. Two OBS deployments would occur with a total of 115 instrumented locations. One deployment consisting of approximately 60 OBSs would be implemented to instrument six profiles off the Oregon coast, and a second deployment consisting of about 55 OBSs would be implemented to instrument three profiles off the coasts of Washington and Vancouver Island. The first deployment off the Oregon coast would occur prior to the start of the proposed survey, after which the R/V *Langseth* would acquire data in the southern portion of the study area. Then 55 of those OBSs would be recovered by the R/V *Oceanus* and re-deployed off the Washington coast and Vancouver Island, so that the R/V *Langseth* can acquire data in the northern portion of the survey area. The OBSs have a height and diameter of approximately 1 m and an approximately 80-kilogram (kg) anchor. To retrieve the OBSs, an acoustic release transponder (pinger) is used to "interrogate" the instrument at a frequency of 8–11 kHz, and a response is received at a frequency of 11.5–13 kHz. The burn-wire release assembly is then activated, and the instrument is released to float to the surface from the anchor, which is not retrieved.

Under the proposed action, a total of 350 independent OBNs spaced 500-m apart would be deployed at 179 nodes along one transect off northern Oregon (22 to 71 nm from the coast at depths of 128 to 2210 m), at 107 nodes along a second transect off central Oregon (30 to 60 nm from the coast at depths of 293 to 2925 m), and at 64 nodes along a third transect off southern Oregon (9 to 26 nm from the coast at depths of 495 to 2731 m). The OBNs are not connected to each other, and there are no cables attached to them. Each OBN has internal batteries, and all data are recorded and stored internally. Each OBN weighs 21 kg in air (9.5 kg in water). As the OBNs are small [330 millimeters (mm) x 289 mm x 115 mm] compact, not buoyant, and lack an anchor-release mechanism, they cannot be deployed/recovered by free-fall as with the OBSs. The nodes would be deployed and retrieved using a remotely operated vehicle (ROV); the ROV would be deployed from the R/V *Oceanus*. The ROV would be fitted with a skid with capacity for 32 units, lowered to the seafloor, and towed at a speed of 0.6 knots at 5 to 10 m above the seafloor between deployment sites. After the 32 units are deployed, the ROV would be retrieved, the skid would be reloaded with another 32 units, and sent back to the seafloor for deployment, and so on. The ROV would recover the nodes 3 days after the completion of the R/V *Langseth* cruise. The nodes would be recovered one by one by a suction mechanism.

Long 15-km-offset MCS data would be acquired along numerous 2-D profiles oriented perpendicular to the margin and located to provide coverage in areas inferred to be rupture patches during past earthquakes and their boundary zones. The survey would also include several strike lines including one continuous line along the continental shelf centered roughly over gravity-inferred fore-arc basins to investigate possible segmentation near the down-dip limit of the seismogenic zone. The margin normal lines would extend ~50 km seaward of the deformation front to image the region of subduction bend faulting in the incoming oceanic plate, and landward of the deformation front to as close to the shoreline as authorized. It is proposed that the southern transects off Oregon be acquired first, followed by the profiles off Washington and Vancouver Island, British Columbia.

In addition to the operations of the airgun array, a multibeam echosounder (MBES), a sub-bottom profiler (SBP), and an Acoustic Doppler Current Profiler (ADCP) would be operated from R/V *Langseth* continuously during the seismic surveys, but not during transit to and from the survey area. The R/V *Oceanus* would operate a single-beam dual-frequency echosounder (4 and 12 kHz) and an ADCP.

The ocean floor would be mapped with the Kongsberg EM122 MBES. The Kongsberg EM122 MBES operates at 10.5–13 kHz and is hull-mounted on the R/V *Langseth*. The maximum source level is 242 dB re 1 μPa·rms. Each ping consists of eight (in water >3,281 ft [1,000 m] deep) or four (<3,281 ft [1,000 m]) successive fan-shaped transmissions, each ensonifying a sector that extends 1° fore–aft. Continuous-wave signals increase from 2 to 15 ms long in water depths up to 8,530 ft (2,600 m), and FM chirp signals up to 100 ms long are used in water >8,530 ft (2,600 m) in depth. The successive transmissions span an overall cross-track angular extent of about 150°, with 2-ms gaps between the pings for successive sectors.

The ocean floor would also be mapped with the Knudsen 3260SBP which transmits a beam as a 27° cone directed downward by a 3.5-kHz transducer in the hull of the R/V *Langseth*. The nominal power output is 10 kilowatts (kW), but the actual maximum radiated power is 3 kW or 222 dB re 1 μPa-m. The ping duration is up to 64 ms, and the ping interval is 1 s. A common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause.

An ADCP would be used to calculate speed of the water current, direction of the current, and the depth in the water column of the current. The ADCP would transmit frequencies at 35-1,200 kHz.

All planned geophysical data acquisition activities would be conducted by L-DEO with on-board assistance by the scientists who have proposed the studies. The vessel would be self-contained, and the crew would live aboard the vessel.

Conservation Measures

Several important measures intended to avoid or minimize the likelihood or extent of adverse impacts to listed species and critical habitat have been incorporated into the design of the project. NSF has stated that the following mitigation measures will be implemented to avoid or minimize adverse effects on marbled murrelets or other listed seabirds encountered during the proposed activities:

- Monitoring by Protected Species Observers (PSOs) for ESA-listed seabirds diving near the vessel.
- Passive acoustic monitoring (PAM).

- PSO data and documentation.
- Mitigation during operations (speed or course alteration; power-down, shut-down, and ramp-up procedures; and special mitigation measures for rare species, species concentrations, and sensitive habitats).
- Five independently contracted PSOs would be on board the survey vessel with rotating shifts to allow two observers to monitor for marine species during daylight hours, and one observer to conduct PAM during day- and night-time seismic operations. In areas where a support vessel would be used, PSOs on board would also monitor for ESA-listed seabirds.

A minimum of one independently contracted PSO would monitor during daylight operational hours for marine species, including ESA-listed seabirds; and two observers 30 min before and during ramp ups during the day and night. In the event an ESA-listed seabird was observed diving or foraging within the designated Exclusion Zone (EZ), the seismic airguns ramp-up would be delayed and, if already operational, would be powered down to a single airgun (so that the seabird remained outside of the EZ of the full array) or shutdown, as appropriate. PSOs would train bridge crew to identify ESA-listed seabirds; during nighttime hours, bridge crew would monitor for any ESA-listed seabirds around the survey vessel, and mitigation measures (e.g., power downs/shutdowns) would be implemented as necessary. In addition, in areas where a support vessel would be used, PSOs on board would also monitor for ESA-listed seabirds and alert R/V *Langseth* PSOs if any are observed.

Deck lighting on the R/V *Langseth* and the R/V *Oceanus* and its ROV, when deployed, is also downward pointing. Curtains/shades are used on cabin windows at night. The fact that the airguns, as a result of their design, direct the majority of the energy downward, and less energy laterally, is also an inherent mitigation measure. Note: the Proposed Action would not involve the intentional hazing of federally listed species which would require a separate permit and formal consultation.

Other Relevant Measures

To reduce the potential for disturbance from acoustic stimuli associated with the activities, L-DEO has proposed to implement mitigation measures for marine species which would also benefit ESA-listed seabirds. As noted above, measures that would be adopted during the planned surveys include (1) reduced survey tracklines in areas of highest sea otter densities and Southern Resident Killer Whale critical habitat; (2) operational restrictions; and (3) additional vessel-based visual mitigation monitoring from a support vessel.

<u>Reduced Survey Transects and Operational Restrictions</u>

Since the initial consultation package was submitted to the FWS, the distance of proposed activities between the coastline and the proposed tracklines and associated ensonified areas have significantly increased. These changes are summarized as follows:

- Proposed tracklines were eliminated off the coast of Washington in water depths <100 m.
- Between Tillamook, OR and Barkley Sound, Canada, in water depths between 100 and 200 m water depths, survey activities would be as follows:
    - Restricted to daylight operations (i.e., from 30 minutes prior to sunrise through 30 minutes following sunset) to ensure that PSOs are able to visually observe the entire

500-m EZ and beyond to implement shutdown procedures.
  - The ensonified areas (the Level B 160dB zone) of proposed tracklines would remain outside of 100m water depths.
  - A support vessel would sail 5 km in advance of the R/V *Langseth* carrying 2 additional PSOs; the additional PSOs would observe, track and communicate relevant marine species presence, including any ESA-listed species, to PSOs on the R/V *Langseth*, alerting them of the potential need to implement shutdown mitigation measures.
- Most tracklines were eliminated off the coast of Oregon in water depths <100 m. A few proposed tracklines remain in water depths <100 m along one section of the coast of Oregon due to a larger protrusion of shallow water topography in this area.
- Proposed tracklines were removed from Southern Resident Killer Whale Critical Habitat established by Canada.
- Within the waters offshore of Washington between Tatoosh Island and the Quillayute River mouth, survey transects must remain 21 km from shore or seaward of the 100 m isobath, whichever is greater. Survey transects must remain seaward of the 100 m isobath between the mouths of the Quillayute River and Grays Harbor.
- If possible, while the R/V *Langseth* is surveying in waters 1,000 m deep or less off the coast of Washington, survey operations will occur in daylight hours only (i.e., from 30 minutes prior to sunrise through 30 minutes following sunset) to ensure that PSOs are able to visually observe the entire 500-m EZ and beyond to implement power/shutdown procedures.

Establishment of Exclusion Zones

If a marbled murrelet is observed within or enters the 500-m EZ, the acoustic source would be powered down or shut down, if necessary. A power down would occur if the marbled murrelet were to dive and/or forage within the 500-m EZ, and a shutdown would occur if the marbled murrelet were to dive/forage within 100-m of the single airgun used during power downs.

The 500-m EZ is intended to be precautionary in the sense that it is designed to minimize impacts to marine species. Although significantly greater distances may be observed from an elevated platform under good conditions, we believe that 500 m is likely regularly attainable for visual monitors using the naked eye during typical conditions.

Vessel-Based Visual Mitigation Monitoring

Visual monitoring requires the use of trained observers (herein referred to as "visual PSOs") to scan the ocean surface visually for the presence of listed species, including diving/foraging ESA-listed seabirds. The effective area to be scanned for seabirds visually includes primarily the EZ. Visual monitoring of the EZ and adjacent waters is intended to establish and maintain zones around the sound source that are clear of listed species that can be visually observed in this manner, thereby reducing or eliminating the potential for injury and minimizing the potential for more severe consequences for animals occurring close to the vessel.

The L-DEO must use dedicated, trained, Service-approved PSOs. The PSOs must have no tasks other than to conduct observational effort, record observational data, and communicate with and instruct relevant vessel crew with regard to the presence of listed species and mitigation requirements. PSO resumes shall be provided to the Service for approval.

At least one of the visual PSOs aboard the vessel must have a minimum of 90 days at-sea experience working in the above-described roles, respectively, during a deep penetration (i.e., "high energy") seismic survey, with no more than 18 months elapsed since the conclusion of the at-sea experience. One visual PSO with such experience shall be designated as the lead for the entire protected species observation team. The lead PSO shall serve as primary point of contact for the vessel operator and ensure all PSO requirements per the conservation measures are met. To the maximum extent practicable, the experienced PSOs should be scheduled to be on duty with those PSOs with appropriate training but who have not yet gained relevant experience.

During survey operations (e.g., any day on which use of the acoustic source is planned to occur, and whenever the acoustic source is in the water, whether activated or not), a minimum of two visual PSOs must be on duty and conducting visual observations at all times during daylight hours (i.e., from 30 minutes prior to sunrise through 30 minutes following sunset). Visual monitoring of the EZ must begin no less than 30 minutes prior to ramp-up and must continue until one hour after use of the acoustic source ceases or until 30 minutes past sunset. Visual PSOs shall coordinate to ensure 360° visual coverage around the vessel from the most appropriate observation posts and shall conduct visual observations using binoculars and the naked eye while free from distractions and in a consistent, systematic, and diligent manner.

PSOs shall establish and monitor the EZ for marbled murrelet and any other ESA-listed seabirds that may be present (e.g., the short-tailed albatross or the Hawaiian petrel). The EZ shall be based upon the radial distance from the edges of the acoustic source (rather than being based on the center of the array or around the vessel itself).

Visual PSOs will immediately communicate all observations to the on-duty acoustic PSO(s), including any determination by the PSO regarding species identification, distance, and bearing and the degree of confidence in the determination. Any observations of listed species by crew members shall be relayed to the PSO team. During good conditions, visual PSOs shall conduct observations when the acoustic source is not operating for comparison of sighting rates and behavior with and without use of the acoustic source and between acquisition periods, to the maximum extent practicable.

Visual PSOs may be on watch for a maximum of four consecutive hours followed by a break of at least one hour between watches and may conduct a maximum of 12 hours of observation per 24-hour period.

<u>Pre-clearance and Ramp-up</u>

Ramp-up (sometimes referred to as a "soft start") means the gradual and systematic increase of emitted sound levels from an airgun array. Ramp-up begins by first activating a single airgun of the smallest volume, followed by doubling the number of active elements in stages until the full complement of an array's airguns are active. Each stage should be approximately the same duration, and the total duration should not be less than approximately 20 minutes. The intent of pre-clearance observation (30 minutes) is to ensure that no ESA-listed seabirds are observed diving/foraging within the EZ prior to the beginning of ramp-up. The ramp-up is expected to have the effect of warning listed species of pending seismic operations and to allow sufficient time for those animals to leave the immediate vicinity. A ramp-up procedure, involving a stepwise increase in the number of airguns firing and total array volume until all operational airguns are activated and the full volume is achieved, is required at all times as part of the activation of the acoustic source. All operators must adhere to the following pre-clearance and ramp-up requirements as follows:

- The operator must notify a designated PSO of the planned start of ramp-up as agreed upon with the lead PSO; the notification time should not be less than 60 minutes prior to the planned ramp-up in order to allow the PSOs time to monitor the exclusion and buffer zones for 30 minutes prior to the initiation of ramp-up procedures during the pre-clearance period.
- Ramp-up procedures shall be scheduled so as to minimize the time spent with the source activated prior to reaching the designated run-in.
- One of the PSOs conducting pre-clearance observations must be notified again immediately prior to initiating ramp-up procedures, and the operator must receive confirmation from the PSO to proceed.
- Ramp-up procedures will not be initiated if any ESA-listed seabird is observed diving/foraging within the applicable EZ. If a listed species is observed diving/foraging within the applicable EZ during the 30-minute pre-clearance period, ramp-up procedures may not begin until the animal(s) has been observed exiting the zones or until an additional 15-minute time period has elapsed with no further sightings of listed species.
- Ramp-up procedures shall begin by activating a single airgun with the lowest volume in the array and shall continue in stages by doubling the number of active airguns at the commencement of each stage, with each stage of approximately the same duration. The duration of each stage shall not be less than 20 minutes. The operator must provide information to the PSO documenting that appropriate ramp-up procedures were followed.
- Visual PSOs must monitor the EZ during ramp-up procedures. Ramp-up procedures must cease, and the source must be shut down if an ESA-listed seabird is observed within the applicable EZ.
- Ramp-up procedures may occur at times of poor visibility if appropriate visual monitoring has occurred with no detections of listed species in the 30 minutes prior to initiating ramp-up procedures. Acoustic source activation may only occur at times of poor visibility where operational planning cannot reasonably avoid such circumstances.
- If the acoustic source is shut down for brief periods (i.e., less than 30 minutes) for reasons other than that described for shutdown (e.g., mechanical difficulty), it may be activated again without ramp-up if PSOs have maintained constant visual and/or acoustic observation and no visual or acoustic detections of listed species have occurred within the applicable EZ. For any longer shutdown, pre-clearance observations and ramp-up procedures are required. For any shutdown at night or in periods of poor visibility (e.g., BSS 4 or greater), initiation of ramp-up procedures is required, but if the shutdown period was brief and constant visual observation was maintained and no ESA-listed species were detected, a pre-clearance period of 30 minutes is not required.
- Testing of the acoustic source involving all associated components requires initiation of ramp-up procedures. Testing limited to individual source components or strings does not require initiation of ramp-up procedures but does require a pre-clearance observation period of 30 minutes.

Shutdown

The shutdown of an airgun array requires the immediate de-activation of all individual airgun components of the array. The PSO on duty will have the authority to delay the start of survey operations or to call for shutdown of the acoustic source if an ESA-listed seabird is detected diving/foraging within the EZ. The operator must also establish and maintain clear lines of communication directly between on-duty PSOs and crew controlling the acoustic source to ensure that shutdown commands are conveyed swiftly while allowing PSOs to maintain watch. When the airgun array is active (i.e., anytime one or more airguns are active, including during ramp-up procedures) and an ESA-listed seabird is observed diving/foraging within the EZ, the acoustic source will be powered down and shut down, if necessary. When power downs and shutdowns are called for by a PSO, the acoustic source will be immediately reduced or deactivated, and any dispute resolved only after implementation of the mitigation measure.

Following a shutdown, airgun activity will not resume until the ESA-listed seabird has been visually observed exiting the area within the 500-m radius EZ or it has not been seen within the 500-m radius EZ for 15 minutes.

Proposed Monitoring and Reporting

<u>Vessel-Based Visual Monitoring</u>

As described above, PSO observations will occur during daytime airgun operations. During seismic operations, at least five visual PSOs would be based aboard the R/V *Langseth*. Monitoring shall be conducted in accordance with the following requirements:

- The operator shall provide PSOs with bigeye binoculars (e.g., 25 x 150; 2.7 view angle; individual ocular focus; height control) of appropriate quality (e.g., Fujinon or equivalent) solely for PSO use. The binoculars shall be pedestal-mounted on the deck at the most appropriate vantage point that provides for optimal listed species observation, PSO safety, and safe operation of the vessel.
- The operator will work with the selected third-party observer provider to ensure that PSOs have all equipment (including backup equipment) needed to adequately perform necessary tasks, including accurate determination of distance and bearing to observed animals.

PSOs must meet the following requirements and qualifications:

- PSOs shall be independent, dedicated, trained visual PSOs and must be employed by a third-party observer provider.
- PSOs shall have no tasks other than to collect observational data and communicate with and instruct relevant vessel crew members with regard to the presence of protected species and mitigation requirements (including brief alerts regarding maritime hazards).
- PSOs shall have successfully completed an approved PSO training course appropriate for their designated task (visual observations).
- The Service must review and approve PSO resumes accompanied by a relevant training course information packet that includes the name and qualifications (i.e., experience, training completed, or educational background) of the instructor(s), the course outline or syllabus, and course reference material as well as a document verifying successful completion of the course.
- The Service shall have one week to approve PSOs from the time the above information is submitted, after which PSOs meeting minimum requirements shall be considered approved.
- PSOs must successfully complete relevant training, including completion of all required

coursework and passing (80 percent or greater) a written and/or oral examination developed for the training program.

- PSOs must have successfully attained a bachelor's degree from an accredited college or university with a major in one of the natural sciences, a minimum of 30 semester hours or equivalent in biological sciences, and at least one undergraduate course in math or statistics.
- The educational requirements may be waived if the PSO has acquired the relevant skills through alternate experience. Requests for such a waiver shall be submitted to the Service and must include written justification. Requests shall be granted or denied (with justification) by the Service within one week of receipt of submitted information. Alternate experience that may be considered includes, but is not limited to (1) secondary education and/or experience comparable to PSO duties; (2) previous work experience conducting academic, commercial, or government-sponsored protected species surveys; or (3) previous work experience as a PSO; the PSO should demonstrate good standing and consistently good performance of PSO duties.

For data collection purposes, PSOs shall use standardized data collection forms, whether hard copy or electronic. PSOs shall record detailed information about any implementation of mitigation requirements, including the distance of listed species to the acoustic source and description of specific actions that ensued, the behavior of the animal(s), any observed changes in behavior before and after implementation of mitigation, and if shutdown was implemented, and the length of time before any subsequent ramp-up of the acoustic source. If required mitigation was not implemented, PSOs shall record a description of the circumstances. At a minimum, the following information must be recorded:

- Vessel name(s) (source vessel and other vessels associated with the seismic survey) and call signs.
- PSO names and affiliations.
- Dates of departures and returns to port with the port name.
- Date and participants of PSO briefings.
- Dates and times (Greenwich Mean Time) of survey effort and times corresponding with PSO effort.
- Vessel location (latitude/longitude) when survey effort began and ended and vessel location at beginning and end of visual PSO duty shifts.
- Vessel heading and speed at beginning and end of visual PSO duty shifts and upon any line change.
- Environmental conditions during the visual survey period (i.e., at the start and finish of the PSO shift and whenever environmental conditions have changed significantly), including BSS and any other relevant weather conditions including cloud cover, fog, sun glare, and overall visibility to the horizon.
- Factors that may have contributed to impaired observations during each PSO shift change or as needed as environmental conditions changed (e.g., vessel traffic, equipment malfunctions).
- Survey activity information, such as acoustic source power output while in operation, number and volume of airguns operating in the array, tow depth of the array, and any other notes of operational significance (e.g., timing of pre-clearance activities, ramp-up procedures, shutdown, testing, shooting, ramp-up completion, end of operations, use of streamers, etc.).

The following information shall be recorded upon visual observation of any listed species:

- Watch status (sighting made by a PSO on or off duty, opportunistically, by a crew member, or

via an alternate vessel/platform).
- Name of PSO who sighted the animal.
- Time of sighting.
- Vessel location at time of sighting.
- Water depth at time of sighting.
- Direction of vessel's travel (compass direction) at the time of sighting.
- Estimated number of animals (high/low/best) sighted.
- Detailed behavior observations of the listed species (e.g., grooming; actively moving away from vessel; diving; note any observed changes in behavior).
- Animal's closest point of approach (CPA) and/or closest distance from any component of the acoustic source.
- Platform activity at time of sighting (e.g., deploying, recovering, testing, shooting, data acquisition, other).
- Description of any actions implemented in response to the sighting (e.g., delays, shutdown, ramp-up) and the time and location of the action.

A draft report summarizing the above information shall be submitted to the Service within 90 days after the end of the cruise. The report shall describe the operations that were conducted and sightings of animals near the operations. The report shall provide full documentation of methods, results, and interpretation pertaining to all monitoring activities. The 90-day report shall summarize the dates and locations of seismic operations, and all ESA-listed seabird sightings (dates, times, locations, activities, associated seismic survey activities). The report shall also include estimates of the number and nature of listed species exposures that occurred above the harassment threshold based on PSO observations.

The draft report shall also include geo-referenced, time-stamped vessel tracklines for all time periods during which airguns were operating. Tracklines should include points recording any change in airgun status (e.g., when the airguns began operating, when they were turned off, or when they changed from full array to single gun or vice versa). GIS files shall be provided in ESRI shapefile format and include the UTC date and time, latitude in decimal degrees, and longitude in decimal degrees. All coordinates shall be referenced to the GCS_North_American_1983 geographic coordinate system. In addition to the draft report, all raw observational data shall be made available to the Service. The draft report must be accompanied by a certification from the lead PSO as to the accuracy of the report, and the lead PSO may submit directly to the Service a statement concerning implementation and effectiveness of the required mitigation and monitoring. A final report must be submitted within 30 days following resolution of any Service comments on the draft report.

<u>Reporting Vessel Strikes or Injured or Dead Animals</u>

See the Incidental Take Statement Terms and Conditions section below for specific procedures required to report, handle, or dispose of any sick or injured individuals of an ESA-listed species.

Term of the Action

The proposed action is scheduled to be implemented from May 20 through July of 2021. However, if there are unanticipated delays, while the total number of survey days will not change, the project time frame could be extended further into the summer period.

Action Area

The action area includes the Cascadia Subduction Zone survey area and transit routes to and from ports. The proposed survey location is approximately 42–51°N, ~124–130°W. Representative survey tracklines are shown in Figure 1 (above). As described further in the EA, some deviation in actual track lines, including the order of survey operations, could be necessary for reasons such as poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Thus, for the surveys, the tracklines could occur anywhere within the coordinates noted above. The surveys are proposed to occur within Exclusive Economic Zones (EEZ) of the U.S. and Canada, as well as in U.S. state waters and Canadian Territorial Waters, ranging in depth from 60 m to 4,400 m.

Analytical Framework for the Jeopardy Determination

In accordance with policy and regulation, the jeopardy determination in this Biological Opinion relies on the following components:

The *Status of the Species*, which evaluates the species' range-wide condition relative to its reproduction, numbers, and distribution, the factors responsible for that condition, and its survival and recovery needs.

The *Environmental Baseline*, which evaluates the condition of the species in the action area relative to its reproduction, numbers, and distribution without the consequences caused by the proposed action, the factors responsible for that condition, and the relationship of the action area to the survival and recovery of the species.

The *Effects of the Action*, which evaluates all future consequences to the species that are reasonably certain to be caused by the proposed action, including the consequences of other activities that are caused by the proposed action, and how those impacts are likely to influence the conservation role of the action area for the species; and

Cumulative Effects, which evaluates the consequences of future, non-Federal activities reasonably certain to occur in the action area on the species, and how those impacts are likely to influence the conservation role of the action area for the species.

In accordance with policy and regulation, the jeopardy determination is made by evaluating the consequences of the proposed Federal action in the context of the species' current range-wide status, taking into account any cumulative effects, to determine if implementation of the proposed action is likely to cause an appreciable reduction in the likelihood of both the survival and recovery of the species in the wild. The key to making this finding is clearly establishing the role of the action area in the conservation of the species as a whole, and how the effects of the proposed action, taken together with cumulative effects, are likely to alter that role.
NOTE: If recovery units were defined for the species in the final listing rule for use in completing jeopardy analyses, pursuant to Service policy, when an action impairs or precludes the capacity of a recovery unit from providing both the survival and recovery function assigned to it, that action may represent jeopardy to the species. When using this type of analysis, the Biological Opinion describes how the consequences of the proposed Federal action on the listed species, taken

together with cumulative effects, affect the capability of the recovery unit to support both the survival and recovery of the species as a whole.

Status of the Species

The marbled murrelet (*Brachyramphus marmoratus*) (marbled murrelet) was listed by the U.S. Fish and Wildlife Service (Service) as a threatened species in Washington, Oregon, and California in 1992. The primary reasons for listing included extensive loss and fragmentation of the older-age forests that serve as nesting habitat for marbled murrelets, and human-induced mortality in the marine environment from gillnets and oil spills (57 FR 45328 [Oct. 1, 1992]). Although some threats such as gillnet mortality and loss of nesting habitat on Federal lands have been reduced since the 1992 listing, the primary threats to species persistence continue (75 FR 3424 [Jan. 21, 2010]).

Life History

The marbled murrelet is a small, fast-flying seabird in the Alcidae family that occurs along the Pacific coast of North America. Marbled murrelets forage for small schooling fish or invertebrates in shallow, nearshore, marine waters and primarily nest in coastal older-aged coniferous forests. The marbled murrelet lifespan is unknown, but is expected to be in the range of 10 to 20 years based on information from similar alcid species (De Santo and Nelson 1995, pp. 36-37). Marbled murrelet nesting is asynchronous and spread over a prolonged season. In Washington, the marbled murrelet breeding season extends from April 1 to September 23. Egg laying and incubation occur from April to early August and chick rearing occurs between late May and September, with all chicks fledging by late September (Hamer et al. 2003; USFWS 2012a).

Marbled murrelets lay a single-egg which may be replaced if egg failure occurs early in the nesting cycle, but this is rare (Nelson 1997, p. 17). During incubation, one adult sits on the nest while the other forages at sea. Adults typically incubate for a 24-hour period, then exchange duties with their mate at dawn. Chicks hatch between May and August after 30 days of incubation. Hatchlings appear to be brooded by an adult for several days (Nelson 1997, p. 18). Once the chick attains thermoregulatory independence, both adults leave the chick alone at the nest for the remainder of the rearing period, except during feedings. Both parents feed the chick, which receives one to eight meals per day (Nelson 1997, p. 18). Most meals are delivered early in the morning while about a third of the food deliveries occur at dusk and intermittently throughout the day (Nelson and Hamer 1995, p. 62).

Marbled murrelets and other fish-eating alcids exhibit wide variations in nestling growth rates. The nestling stage of marbled murrelet development can vary from 27 to 40 days before fledging (De Santo and Nelson 1995, p. 45). The variations in alcid chick development are attributed to constraints on feeding ecology, such as unpredictable and patchy food distributions, and great distances between feeding and nesting sites (Øyan and Anker-Nilssen 1996, p. 830). Food limitation during nesting often results in poor growth, delayed fledging, increased mortality of chicks, and nest abandonment by adults (Øyan and Anker-Nilssen 1996, p. 836).

Marbled murrelets are believed to be sexually mature at 2 to 4 years of age (Nelson 1997, p. 19). Adult birds may not nest every year, especially when food resources are limited. For example, in central California, the proportion of marbled murrelets attempting to breed was more than four times higher (50 percent versus 11 percent) in a year when prey availability was apparently good than in a year when more foraging effort was required (Peery et al. 2004, p. 1095). In Oregon, there was similarly a four-fold increase in vacancy rates of previously occupied nesting habitat following the poorest ocean conditions, as compared with the years following the best ocean conditions (Betts et al. 2020, p. 6). In 2017, none of the 61 marbled murrelets radio-tagged in Oregon attempted nesting, likely because anomalous ocean conditions reduced prey availability (Horton et al. 2018, p. 77). At other times and places, radio-telemetry and demographic modeling indicate that the proportion of adults breeding in a given year may vary from 5 to 95 percent (Lorenz et al. 2017, p. 312; McShane et al. 2004, p. 3-5). In other words, in some years, very few marbled murrelets attempt nesting, but in other years, almost all breeding-age adults may initiate nesting.

Marbled Murrelets in the Marine Environment

Marbled murrelets spend most (>90 percent) of their time at sea. They generally forage in pairs on the water, but they also forage solitarily or in small groups. In addition to foraging, their activities in the marine environment include preening, social behaviors, and loafing. Following the breeding season, marbled murrelets undergo the pre-basic molt, in which they exchange their breeding plumage for their winter plumage. They replace their flight feathers during this molt, and for a few weeks they are flightless. Therefore, they spend this entire period at sea. Their preferred marine habitat includes sheltered, nearshore waters, although they occur farther offshore in some locations and during the nonbreeding season (Huff et al. 2006, p. 19).

<u>Breeding Season Distribution</u>

The marbled murrelet is widely distributed in nearshore waters along the west coast of North America. It occurs primarily within 5 km of shore (in Alaska, within 50 km), and primarily in protected waters, although its distribution varies with coastline topography, river plumes, riptides, and other physical features (Nelson 1997, p. 3). For example, along the Pacific coast of Washington, the most heavily-used area during the breeding season extends to at least 8 km from the coast, with use in some years concentrated in the outer portions of this area (Bentivoglio et al. 2002, p. 29; McIver et al., in press, pp. 34, 85; Menza et al. 2015, pp. 16, 20-21). The distribution of marbled murrelets in marine waters during the summer breeding season is highly variable along the Pacific coast, with areas of high density occurring along the Strait of Juan de Fuca in Washington, the central Oregon coast, and northern California (Raphael et al. 2015, p. 20). Low-density areas or gaps in marbled murrelet distribution occur in central California, and along the southern Washington coast (Raphael et al. 2015, p. 21). Marbled murrelet marine habitat use is strongly associated with the amount and configuration of nearby terrestrial nesting habitat (Raphael et al. 2015, p. 17). In other words, they tend to be present in marine waters adjacent to areas of suitable breeding habitat. Local aggregations or "hot spots" of marbled murrelets in nearshore marine waters are strongly associated with landscapes that support large, contiguous areas of mature and old-growth forest. In Puget Sound and along the Strait of Juan de Fuca, these "hot spots" are also strongly associated with a low human footprint in the marine environment, for example, areas natural shorelines and relatively little vessel traffic (Raphael et al. 2016a, p. 106).

Non-breeding adults and subadults are thought to occur in similar areas as breeding adults. This species does occur farther offshore during the breeding season, but in much reduced numbers (Drew and Piatt 2020; Strachan et al. 1995, p. 247). Their offshore occurrence is probably related to current upwelling and plumes during certain times of the year that tend to concentrate their prey species. Even within the breeding season, individual marbled murrelets may make large movements, and large average marine home ranges (505 km^2 and 708 km^2, respectively) have been reported for northern California and Washington (Hébert and Golightly 2008, p. 99; Lorenz et al. 2017, p. 318).

Non-breeding Season Distribution

Marbled murrelet marine habitat use during the non-breeding season is poorly documented, but they are present near breeding sites year-round in most areas (Nelson 1997, p. 3). Marbled murrelets exhibit seasonal redistributions following the pre-basic molt (Peery et al. 2008a, p. 119), and can move up to 750 km from their breeding season locations (Hébert and Golightly 2008, p. 101; Adrean et al. 2018). The southern end of the range extends as far south as the Southern California Bight; but some individuals also move northward at the end of the breeding season (Hall et al. 2009, p. 5081; Peery et al. 2008a, p. 121). Generally they are more dispersed and may be found farther offshore than during the breeding season, up to approximately 50 miles from shore (Adams et al. 2014; Ballance 2015, in litt.; Drew and Piatt 2020; Pearson 2019, p. 5; Speich and Wahl 1995, p. 322).

The highest concentrations likely still occur close to shore and in protected waters, but given the limited data available regarding non-breeding season marbled murrelet distribution or densities, a great deal of uncertainty remains (Nelson 1997, p. 3; Pearson 2019, p. 5). More information is available regarding non-breeding season marbled murrelet density and distribution in some areas of Puget Sound. Marbled murrelets move from the outer exposed coasts of Vancouver Island and the Straits of Juan de Fuca into the sheltered and productive waters of northern and eastern Puget Sound (Beauchamp et al. 1999, entire; Burger 1995, p. 297; Speich and Wahl 1995, p. 325). However, in central and southern Puget Sound, marbled murrelet densities are lower during the non-breeding season than they are during the breeding season (McIver et al. 2021, pp. 11-17; Pearson and Lance 2020, p. 12). Known areas of winter concentration include and southern and eastern end of Strait of Juan de Fuca (primarily Sequim, Discovery, and Chuckanut Bays), San Juan Islands and Puget Sound, Washington (Speich and Wahl 1995, p. 314).

Foraging and Diet

Marbled murrelets dive and swim through the water by using their wings in pursuit of their prey; their foraging and diving behavior is restricted by physiology. They usually feed in shallow, nearshore water less than 30 m (98 ft) deep, which seems to provide them with optimal foraging conditions for their generalized diet of small schooling fish and large, pelagic invertebrates: Pacific sand lance (*Ammodytes personatus*), northern anchovy (*Engraulis mordax*), Pacific herring (*Clupea harengus*), surf smelt (*Hypomesus* sp.), euphausiids, mysids, amphipods, and other species (Nelson 1997, p. 7). However, they are assumed to be capable of diving to a depth of 47 m (157 ft) based on their body size and diving depths observed for other alcid species (Mathews and Burger 1998, p. 71).

Contemporary studies of marbled murrelet diets in the Puget Sound–Georgia Basin region indicate that Pacific sand lance now make up the majority of the marbled murrelet diet

(Gutowsky et al. 2009, p. 251). Historically, energy-rich fishes such as herring and northern anchovy comprised the majority of the marbled murrelet diet (Becker and Beissinger 2006, p. 470; Gutowsky et al. 2009, p. 247). This is significant because sand lance have the lowest energetic value of the fishes that marbled murrelets commonly consume. For example, a single northern anchovy has nearly six times the energetic value of a sand lance of the same size (Gutowsky et al. 2009, p. 251), so a marbled murrelet would have to eat six sand lance to get the equivalent energy of a single anchovy. Reductions in the abundance of energy-rich forage fish species is likely a contributing factor in the poor reproduction in marbled murrelets (Becker and Beissinger 2006, p. 470).

The duration of dives appears to depend upon age (adults vs. juveniles), water depth, visibility, and depth and availability of prey. Dive duration has been observed ranging from 8 seconds to 115 seconds, although most dives are between 25 to 45 seconds (Day and Nigro 2000; Jodice and Collopy 1999; Thoresen 1989; Watanuki and Burger 1999). Diving bouts last over a period of 27 to 33 minutes (Nelson 1997, p. 9). They forage in deeper waters when upwelling, tidal rips, and daily activity of prey concentrate prey near the surface (Strachan et al. 1995). Marbled murrelets are highly mobile, and some make substantial changes in their foraging sites within the breeding season. For example, Becker and Beissinger (2003, p. 243) found that marbled murrelets in California responded rapidly (within days or weeks) to small-scale variability in upwelling intensity and prey availability by shifting their foraging behavior and habitat selection within a 100-km (62-mile) area. In Washington, changes in water temperature, likely also related to prey availability, influence foraging habitat use, but the influence of upwelling is less clear (Lorenz et al. 2017, pp. 315, 318).

For more information on marbled murrelet use of marine habitats, see literature reviews in McShane et al. 2004, USFWS 2009, and USFWS 2019.

Marbled Murrelets in the Terrestrial Environment

Marbled murrelets are dependent upon older-age forests, or forests with an older tree component, for nesting habitat (Hamer and Nelson 1995, p. 69). Specifically, marbled murrelets prefer high and broad platforms for landing and take-off, and surfaces which will support a nest cup (Hamer and Nelson 1995, pp. 78-79). In Washington, marbled murrelet nests have been found in live conifers, specifically, western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), Douglas-fir (*Pseudotsuga menziesii*), and western red cedar (*Thuja plicata*) (Hamer and Nelson 1995; Hamer and Meekins 1999). Most marbled murrelets appear to nest within 37 miles of the coast, although occupied behaviors have been recorded up to 52 miles inland, and marbled murrelet presence has been detected up to 70 miles inland in Washington (Huff et al. 2006, p. 10). Nests occur primarily in large, older-aged trees. Overall, nests have been found in trees greater than 19 inches in diameter-at-breast and greater than 98 ft tall. Nesting platforms include limbs or other branch deformities that are greater than 4 inches in diameter and are at greater than 33 ft above the ground. Substrate such as moss or needles on the nest platform is important for protecting the egg and preventing it from falling off (Huff et al. 2006, p. 13).

Marbled murrelets do not form the dense colonies that are typical of most other seabird species. Limited evidence suggests they may form loose colonies in some cases (Ralph et al. 1995). The reliance of marbled murrelets on cryptic coloration to avoid detection suggests they utilize a wide spacing of nests in order to prevent predators from forming a search image (Ralph et al.

1995). Individual marbled murrelets are suspected to have fidelity to nest sites or nesting areas, although this is has only been confirmed with marked birds in a few cases (Huff et al. 2006, p. 11). There are at least 15 records of marbled murrelets using nest sites in the same or adjacent trees in successive years, but it is not clear if they were used by the same birds (McShane et al. 2004, p. 2-14). At the landscape scale, marbled murrelets are probably faithful to specific watersheds for nesting (McShane et al. 2004, p. 2-14). Marbled murrelets have been observed visiting nesting habitat during non-breeding periods in Washington, Oregon, and California which may indicate adults are maintaining fidelity and familiarity with nesting sites and/or stands (Naslund 1993; O'Donnell et al. 1995, p. 125).

Loss of nesting habitat reduces nest site availability and displaces any marbled murrelets that may have had nesting fidelity to the logged area (Raphael et al. 2002, p. 232). Marbled murrelets have demonstrated fidelity to nesting stands and in some areas, fidelity to individual nest trees (Burger et al. 2009, p. 217). Marbled murrelets returning to recently logged areas may not breed for several years or until they have found suitable nesting habitat elsewhere (Raphael et al. 2002, p. 232). The potential effects of displacement due to habitat loss include nest site abandonment, delayed breeding, failure to initiate breeding in subsequent years, and failed breeding due to increased predation risk at a marginal nesting location (Divoky and Horton 1995, p. 83; Raphael et al. 2002, p. 232). Each of these outcomes has the potential to reduce the nesting success for individual breeding pairs, and could ultimately result in the reduced recruitment of juvenile birds into the local population (Raphael et al. 2002, pp. 231-233).

Detailed information regarding the life history and conservation needs of the marbled murrelet are presented in the *Ecology and Conservation of the Marbled murrelet* (Ralph et al. 1995), the Service's 1997 *Recovery Plan for the Marbled murrelet* (USFWS 1997), and in subsequent 5-year status reviews (McShane et al. 2004; USFWS 2009; USFWS 2019).

Terrestrial Distribution

Marbled murrelets are distributed along the Pacific coast of North America, with birds breeding from central California through Oregon, Washington, British Columbia, southern Alaska, westward through the Aleutian Island chain, with presumed breeding as far north as Bristol Bay (Nelson 1997, p. 2), and non-breeding distribution extending as far south as the Southern California Bight (Hall et al. 2009, p. 5081). The federally listed marbled murrelet population in Washington, Oregon, and California is classified by the Service as a distinct population segment (75 FR 3424). The coterminous United States population of marbled murrelets is considered significant as the loss of this distinct population segment would result in a significant gap in the range of the taxon and the loss of unique genetic characteristics that are significant to the taxon (75 FR 3430).

The inland nesting distribution of marbled murrelets is strongly associated with the presence of mature and old-growth conifer forests. Marbled murrelets have been detected farther than100 km inland in Washington (70 miles).The inland distribution in the southern portion of the species range is associated with the extent of the hemlock/tanoak vegetation zone which occurs up to 16-51 km inland (10-32 miles) (Evans Mack et al. 2003, p. 4). Although marbled murrelets are distributed throughout their historical range, the area of occupancy within their historic range appears to be reduced from historic levels. The distribution of the species also exhibits five areas of discontinuity: a segment of the border region between British Columbia, Canada and

Washington; southern Puget Sound, WA; Destruction Island, WA to Tillamook Head, OR; Humboldt County, CA to Half Moon Bay, CA; and the entire southern end of the breeding range in the vicinity of Santa Cruz and Monterey Counties, CA (McShane et al. 2004, p. 3-70).

Marbled murrelets use inland habitats primarily for nesting, including egg laying, incubation, and feeding of nestlings. In addition, marbled murrelets have been observed in nesting habitat demonstrating social behaviors, such as circling and vocalizing, in groups of up to ten birds (Nelson and Peck 1995, p. 51). Nest sites tend to be clustered spatially, indicating that although marbled murrelets are not colonial seabirds, they also are not strictly solitary in their nesting behavior; in other words, at least in some circumstances, they nest semi-colonially (Conroy et al. 2002, p. 131; Naslund et al. 1995, p. 12). In California and southern Oregon, marbled murrelets occupy habitat more frequently when there is other occupied habitat within 5 km (Meyer et al. 2002, p. 103), and we assume that the same is true in Washington. Usually, multiple nests can be found in a contiguous forested area, even in places where they are not strongly clustered (Evans Mack et al. 2003, p. 6). In Oregon, marbled murrelets were ten times more likely to nest in previously unoccupied nesting habitat where recordings of marbled murrelet calls had been broadcast the previous year than in control sites where no recordings were played, indicating that marbled murrelets select nesting habitat in part based on the apparent presence of conspecifics (Valente et al. 2021, p. 50).

Distribution of Nesting Habitat

The loss of nesting habitat was a major cause of the marbled murrelet's decline over the past century and may still be contributing as nesting habitat continues to be lost to fires, logging, insects, tree diseases, and wind storms (Miller et al. 2012, p. 778; Raphael et al. 2016b, pp. 80-81). Due mostly to historical timber harvest, only a small percentage (~11 percent) of the habitat-capable lands within the listed range of the marbled murrelet currently contain potential nesting habitat (Raphael et al. 2016b, p. 69).

Monitoring of marbled murrelet nesting habitat within the Northwest Forest Plan (NWFP, equivalent to Conservation Zones 1 through 5) area indicates nesting habitat declined from an estimated 2.53 million acres in 1993 to an estimated 2.23 million acres in 2012, a decline of about 12.1 percent (Raphael et al. 2016b, p. 72). Fire has been the major cause of nesting habitat loss on Federal lands, while timber harvest is the primary cause of loss on non-Federal lands (Raphael et al. 2016b, p. 79). While most (60 percent) of the potential habitat is located on Federal reserved-land allocations, a substantial amount of nesting habitat occurs on non-federal lands (34 percent) (Table 1).

In Zone 6, monitoring of nesting habitat has not been carried out in the same way as within the NWFP area. Most of the existing nesting habitat within Zone 6 is located on state and local public lands, where logging has not occurred (Halbert and Singer 2017, p. 1). During August of 2020, over 60 percent of the nesting habitat in Zone 6 burned in a large wildfire (Singer 2021, in litt.). Preliminary data indicate that this fire has resulted in substantial habitat loss, though some lost habitat features may recover over the next several years. Many trees within the burned areas survived the fire, including the "Father of the Forest" redwood where marbled murrelet nesting has been documented repeatedly (California Department of Parks and Recreation 2020, p. 2; Halbert and Singer 2017, p. 35); however, suitable platforms likely burned even in trees that survived the fire, leading to a loss of suitability for many years as branches regrow (Singer 2020, in litt.). In a sample of 40 previously identified potential nest trees within Big Basin State Park, 22 trees (55 percent) appeared to have survived the fire (Singer 2021, in litt.). If this sample is representative, more than one quarter (i.e. 45 percent x 60 percent) of potential marbled murrelet nest trees in Zone 6 may have been killed by the fire, with platform structures lost from a substantial percentage of the remaining trees. Future monitoring will be necessary to refine these estimates of habitat loss.

Table 1. Estimates of higher-quality marbled murrelet nesting habitat by State and major land ownership within the area of the NWFP – derived from 2012 data.

State	Habitat capable lands (1,000s of acres)	Habitat on Federal reserved lands (1,000s of acres)	Habitat on Federal non-reserved lands (1,000s of acres)	Habitat on non-federal lands (1,000s of acres)	Total potential nesting habitat (all lands) (1,000s of acres)	Percent of habitat capable land that is currently in habitat
WA	10,851.1	822.4	64.7	456	1,343.1	12 %
OR	6,610.4	484.5	69.2	221.1	774.8	12 %
CA	3,250.1	24.5	1.5	82.9	108.9	3 %
Totals	20,711.6	1,331.4	135.4	760	2,226.8	11 %
Percent		60 %	6 %	34 %	100 %	-

Source: (Raphael et al. 2016b, pp. 78-81).

Population Status

The 1997 *Recovery Plan for the Marbled murrelet* (USFWS 1997) identified six Conservation Zones throughout the listed range of the species: Puget Sound (Conservation Zone 1), Western Washington Coast Range (Conservation Zone 2), Oregon Coast Range (Conservation Zone 3), Siskiyou Coast Range (Conservation Zone 4), Mendocino (Conservation Zone 5), and Santa Cruz Mountains (Conservation Zone 6) (Figure 3). Conservation Zones are the functional equivalent of recovery units as defined by Service policy (USFWS 1997, p. 115). The subpopulations in each Zone are not discrete. There is some movement of marbled murrelets between Zones, as indicated by radio-telemetry studies (e.g., Bloxton and Raphael 2006, p. 162), but the degree to which marbled murrelets migrate between Zones is unknown. Genetic studies also indicate that there is movement of marbled murrelets between Zones, although Zone 6 is more isolated genetically than the other Zones (Friesen et al. 2005, pp. 611-612; Hall et al. 2009, p. 5080; Peery et al. 2008b, pp. 2757-2758; Peery et al. 2010, p. 703; Vásquez-Carrillo et al. 2014, pp. 251-252). For the purposes of consultation, the Service treats each of the Conservation Zones as separate sub-populations of the listed marbled murrelet population.

Population Status and Trends

Population estimates for the marbled murrelet are derived from marine surveys conducted during the nesting season as part of the NWFP effectiveness monitoring program. Surveys from 2001 to 2018 indicated that the marbled murrelet population in Conservation Zones 1 through 5 (NWFP area) increased at a rate of 0.5 percent per year (McIver et al. 2021, p. 4). While the trend estimate across this period is slightly positive, the confidence intervals are tight around zero

(95% confidence interval [CI]: -0.5 to 1.5 percent), indicating that at the scale of the NWFP area, the population is changing very little (McIver et al. 2021, p. 4) (Table 2). At the state scale, Washington exhibited a significant declining trend between 2001 and 2018 (3.9% decrease per year, while Oregon and California showed significant positive trends (OR = 2.2% increase per year; CA = 4.6% increase per year (McIver et al. 2021, p. 4) (Table 2). Zone 1 shows the greatest decline of 5.0 percent per year, while the decline in Zone 2 is smaller, 2.2 percent per year, and less statistically certain (Table 2). Zone 4 shows the greatest increase of 3.5 percent per year, while Zone 3 shows a smaller, and less statistically certain, increase of 1.5 percent per year (Table 2). There is great uncertainty regarding the trend in Zone 5 due to the infrequency of surveys in that zone and the influence of a single anomalous year in 2017 (McIver et al., in press, p. 37). No trend estimate is available for Zone 6.

While the direct causes for population declines in Washington are unknown, potential factors include the loss of nesting habitat, including cumulative and time-lag effects of habitat losses over the past 20 years (an individual marbled murrelets potential lifespan), changes in the marine environment reducing the availability or quality of prey, increased densities of nest predators, and emigration (Miller et al. 2012, p. 778). As with nesting habitat loss, marine habitat degradation is most prevalent in the Puget Sound area, where anthropogenic activities (e.g., shipping lanes, boat traffic, shoreline development) are an important factor influencing the marine distribution and abundance of marbled murrelets in Conservation Zone 1 (Falxa and Raphael 2016, p. 110).

The most recent population estimate for the entire Northwest Forest Plan area in 2019 was 21,200 marbled murrelets (95 percent confidence interval [CI]: 16,400 to 26,000 birds) (McIver et. al 2021, p. 10). The largest and most stable marbled murrelet subpopulations now occur off the Oregon and northern California coasts, while subpopulations in Washington have experienced the greatest rates of decline. Marbled murrelet zones are now surveyed on an every other-year basis, so the last year that an extrapolated range-wide estimate for all zones combined is 2018 (Table 2).

The marbled murrelet subpopulation in Conservation Zone 6 (central California- Santa Cruz Mountains) is outside of the NWFP area and is monitored separately by California State Parks and the U.S. Geological Survey using similar at-sea survey methods (Felis et al. 2020, p. 1). Surveys in Zone 6 indicate a small population of marbled murrelets with no clear trends. Population estimates from 2001 to 2018 have fluctuated from a high of 699 marbled murrelets in 2003, to a low of 174 marbled murrelets in 2008 (Felis et al. 2020 p. 7). In 2019, surveys indicated an estimated population of 404 marbled murrelets in Zone 6 (95% CI: 272-601) (Felis et al. 2020, p. 7) (Table 3).

Table 2. Summary of marbled murrelet population estimates and trends (2001-2019/2020) at the scale of Conservation Zones and states.

Zone	Year	Estimated number of marbled murrelets	95% CI Lower	95% CI Upper	Average density (at sea) (marbled murrelets /km²)	Average annual rate of population change (%)	95% CI Lower	95% CI Upper
1	2020	3,143	2,030	4,585	0.899	-5.0	-7.0	-2.9
2	2019	1,657	745	2,752	1.004	-2.2	-5.7	+1.5
3	2020	8,359	5,569	11,323	5.239	+1.5	+0.02	+3.1
4	2019	6,822	5,576	11,063	5.885	+3.5	+1.6	+5.5
5	2017	868	457	1,768	0.983	+7.2	-4.4	+20.3
Zones 1-5	2019	21,230	16,446	26,015	2.417	+0.5	-0.5	+1.5
Zone 6	2019	404	272	601	na	na	na	na
WA	2019	5,151	2,958	7,344	1.00	-3.9	-5.4	-2.4
OR	2019	10,339	7,070	13,607	4.99	+2.2	+0.9	+3.4
CA Zones 4 & 5	2019	5,741	3,894	7,588	3.67	+4.6	+2.7	+6.5

Sources: (McIver et al. 2021, pp. 16-20, Felis et al. 2020, p. 7).

Factors Influencing Population Trends

Population monitoring data show marbled murrelet populations declining in Washington but increasing in Oregon and northern California (McIver et al. 2021, p. 4). Marbled murrelet population size and distribution is strongly and positively correlated with the amount and pattern (large contiguous patches) of suitable nesting habitat, and population trend is most strongly correlated with trend in nesting habitat, although marine factors also contribute to this trend (Raphael et al. 2016a, p. 115). From 1993 to 2012, there was a net loss of about 2 percent of potential nesting habitat from on federal lands, compared to a net loss of about 27 percent on nonfederal lands, for a total cumulative net loss of about 12.1 percent across the NWFP area (Raphael et al. 2016b, p. 72). Cumulative habitat losses since 1993 have been greatest in Washington, with most habitat loss in Washington occurring on non-Federal lands due to timber harvest (Raphael et al. 2016b, pp. 80-81) (Table 3).

Table 3. Distribution of higher-suitability marbled murrelet nesting habitat by Conservation Zone, and summary of net habitat changes from 1993 to 2012 within the NWFP area.

Conservation Zone	1993	2012	Change (acres)	Change (percent)
Zone 1 - Puget Sound/Strait of Juan de Fuca	829,525	739,407	-90,118	-10.9 %
Zone 2 - Washington Coast	719,414	603,777	-115,638	-16.1 %
Zone 3 - Northern to central Oregon	662,767	610,583	-52,184	-7.9 %
Zone 4 - Southern Oregon - northern California	309,072	256,636	-52,436	-17 %
Zone 5 - north-central California	14,060	16,479	+2,419	+17.2 %

Source: (Raphael et al. 2016b, pp. 80-81).

The decline in marbled murrelet populations from 2001 to 2013 is weakly correlated with the decline in nesting habitat, with the greatest declines in Washington, and the smallest declines in California, indicating that when nesting habitat decreases, marbled murrelet abundance in adjacent marine waters may also decrease. At the scale of Conservation Zones, the strongest correlation between habitat loss and marbled murrelet decline is in Zone 2, where marbled murrelet habitat has declined most steeply, and marbled murrelet populations have also continued to decline. However, these relationships are not linear, and there is much unexplained variation (Raphael et al. 2016a, p. 110). While terrestrial habitat amount and configuration (i.e., fragmentation) and the terrestrial human footprint (i.e., cities, roads, development) appear to be strong factors influencing marbled murrelet distribution in Zones 2-5; terrestrial habitat and the marine human footprint (i.e., shipping lanes, boat traffic, shoreline development) appear to be the most important factors that influence the marine distribution and abundance of marbled murrelets in Zone 1 (Raphael et al. 2016a, p. 106).

Like other marine birds, marbled murrelets depend for their survival on their ability to successfully forage in the marine environment. Despite this, it is apparent that the location, amount, and landscape pattern of terrestrial nesting habitat are strongest predictors of the spatial and temporal distributions of marbled murrelets at sea during the nesting season (Raphael et al. 2015, p. 20). Outside of Zone 1, various marine habitat features (e.g., shoreline type, depth, temperature, human footprint, etc.) apparently have only a minor influence on marbled murrelet distribution at sea. Despite this relatively weak spatial relationship, marine factors, and especially any decrease in forage species, likely play an important role in explaining the apparent population declines, but the ability to detect or model these relationships is currently limited (Raphael et al. 2015, p. 20). Over both the long and short term, there is evidence that diet quality is related to marbled murrelet abundance, the likelihood of nesting attempts, reproductive success (Becker et al. 2007, p. 276; Betts et al. 2020, pp. 6-7; Norris et al. 2007, p. 881).

The interplay between marine and terrestrial habitat conditions also influences marbled murrelet population dynamics. A recent analysis indicates that in Oregon, over a 20-year period, nesting activity was most likely to occur following years with cool ocean temperatures (indicating good forage availability), and at sites where large blocks of mature forest were close to the coast (Betts et al. 2020, pp. 5-9). Even when ocean conditions were poor, nesting marbled murrelets colonized new sites that were surrounded by abundant old forest, but during good ocean conditions, even sites with less old forest could be colonized (Betts et al. 2020, p. 6). This relationship has not been investigated in other parts of the range, but is consistent with observations in Washington, where marbled murrelets occupy nesting habitat at lower rates, often fly long distances to reach foraging areas, breed at very low observed rates, and the population continues to decline (Lorenz et al. 2017, pp. 312-313, 318; McIver et al. 2021, p. 20).

Population Models

Prior to the use of survey data to estimate trend, demographic models were more heavily relied upon to generate predictions of trends and extinction probabilities for the marbled murrelet population (Beissinger 1995; Cam et al. 2003; McShane et al. 2004; USFWS 1997). However, marbled murrelet population models remain useful because they provide insights into the demographic parameters and environmental factors that govern population stability and future extinction risk, including stochastic factors that may alter survival, reproductive, and immigration/emigration rates.

In a report developed for the *5-year Status Review of the Marbled murrelet in Washington, Oregon, and California* (McShane et al. 2004, pp. 3-27 to 3-60), models were used to forecast 40-year marbled murrelet population trends. A series of female-only, multi-aged, discrete-time stochastic Leslie Matrix population models were developed for each conservation zone to forecast decadal population trends over a 40-year period with extinction probabilities beyond 40 years (to 2100). The authors incorporated available demographic parameters (Table 4) for each conservation zone to describe population trends and evaluate extinction probabilities (McShane et al. 2004,
p. 3-49).

McShane et al. (2004) used mark-recapture studies conducted in British Columbia by Cam et al. (2003) and Bradley et al. (2004) to estimate annual adult survival and telemetry studies or at-sea survey data to estimate fecundity. Model outputs predicted -3.1 to -4.6 percent mean annual rates of population change (decline) per decade the first 20 years of model simulations in marbled murrelet Conservation Zones 1 through 5 (McShane et al. 2004, p. 3-52). Simulations for all zone populations predicted declines during the 20 to 40-year forecast, with mean annual rates of -2.1 to -6.2 percent, depending on Zone and decade (McShane et al. 2004, p. 3-52). While these modeled rates of decline are similar to those observed in Washington (McIver et al. 2021, p. 20), the simulated projections at the scale of Zones 1-5 do not match the apparently increasing populations observed in Oregon and California during the 2001-2019 monitoring period. Comparable trend information is not available for Zone 6 in central California.

Table 4. Rangewide marbled murrelet demographic parameter values based on four studies all using Leslie Matrix models.

Demographic Parameter	Beissinger 1995	Beissinger and Nur 1997*	Beissinger and Peery (2007)	McShane et al. 2004
Juvenile Ratio (R)	0.10367	0.124 or 0.131	0.089	0.02 - 0.09
Annual Fecundity	0.11848	0.124 or 0.131	0.06-0.12	-
Nest Success	-	-	0.16-0.43	0.38 - 0.54
Maturation	3	3	3	2 - 5

Estimated Adult Survivorship	85 % – 90%	85 % – 88 %	82 % - 90 %	83 % – 92 %

*In U.S. Fish and Wildlife (1997).

Reproduction

Overall fecundity is a product of the proportion of marbled murrelets that attempt nesting and the proportion of nest attempts that succeed. Telemetry studies can be used to estimate both the proportion of marbled murrelets attempting nesting, and the proportion of nest attempts that succeed. When telemetry estimates are not available, at-sea surveys that separately count the number of hatch-year and after-hatch-year birds can be used to estimate productivity. Telemetry estimates are typically preferred over marine counts for estimating breeding success due to fewer biases (McShane et al. 2004, p. 3-2). However, because of the challenges of conducting telemetry studies, estimating marbled murrelet reproductive rates with an index of reproduction, referred to as the juvenile ratio ($\hat{R}$),[1] continues to be important, despite some debate over use of this index (see discussion in Beissinger and Peery 2007, p. 296).

Marbled murrelet fecundity is likely limited in part by low rates of nesting attempts in some parts of the range. Radio-telemetry monitoring Washington between 2004 and 2008 indicated only a small portion of 158 tagged adult birds actually attempted to nest (13 to 20 percent) (Lorenz et al. 2017, p. 316; Raphael and Bloxton 2009, p. 165). Studies from California and Oregon also report low rates. Two studies from central and northern California reported that an average of around 30 percent of radio-tagged marbled murrelets attempted to nest (Hébert and Golightly 2006, p. 130; Peery et al. 2004, p. 1093). In preliminary results from a study in Oregon, only 11 out of 203 marbled murrelets (5 percent) tagged between 2017 and 2019, attempted to nest (Adrean 2021, pers. comm.). This represents the lowest rate yet reported for the species; however, the study is not yet complete and is therefore not fully comparable to the others cited above. These low rates of nesting are not intrinsic to the species; other studies outside of the listed range reported that between 46 and 80 percent of marbled murrelets attempted to breed each year (Barbaree et al. 2014, p. 177; Bradley et al. 2004, p. 323), and most population modeling studies suggest a range of 80 to 95 percent of adults breed each year (McShane et al. 2004, p. 3-5). The process of radio-tagging or the additional weight and drag of the radio tag itself may reduce the probability that a tagged individual will attempt to breed, but studies reporting higher rates of attempted nesting used similar radio tags, so radio-telemetry methods do not account for differences between the studies conducted in the listed range and those conducted elsewhere (Peery et al. 2004, p. 1094).

Although difficult to obtain, nest success rates[2] are available from telemetry studies conducted in California (Hébert and Golightly 2006; Peery et al. 2004, p. 1094), Washington (Lorenz et al. 2017, p. 312; Lorenz et al. 2019, p. 160), and, preliminarily, in Oregon (Adrean et al. 2019, p. 2). In northwestern Washington, Lorenz and others (2017, p. 312; 2019, pp. 159-160) documented a nest success rate of 0.20 (3 chicks fledging from 15 nest starts). In central California, marbled

[1] The juvenile ratio ($\hat{R}$) for marbled murrelets is derived from the relative abundance of hatch-year (HY; 0-1 yr-old) to after-hatch-year (AHY; 1+ yr-old) birds (Beissinger and Peery 2007, p. 297) and is calculated from marine survey data. All ratios presented here are date-corrected using the methods of Peery et al. (2007, p. 234) to account adults incubating and chicks not yet fledged at the time of the survey.

[2] Nest success here is defined by the annual number of known hatchlings departing from the nest (fledging) divided by the number of nest starts.

murrelet nest success is 0.16 (Peery et al. 2004, p. 1098) and in northern California it ranges from 0.069 to 0.243 (Hébert and Golightly 2006, p. 129). In Oregon, preliminary results from a telemetry study indicate that 3 of 7 active nests successfully fledged young, a rate of 0.43, but this success rate may not be comparable to the others reported above; for example, it is not clear whether it includes all nesting attempts (Adrean et al. 2019, p. 2).

At least one telemetry study reported overall fecundity rates, combining both the rates of nesting attempts with the rates of fledging success. In central California, the fecundity rate was estimated to be 0.027, or 2.7 female chicks produced per year for every 100 females of breeding age (Peery et al. 2004, p. 1094). In other studies, the overall fecundity rate is not known, because it is not clear how many of the radio-tagged birds were of breeding age. However, in northern California, of 102 radio-tagged birds, at least two and at most six successfully produced fledglings (Hébert and Golightly 2006, pp. 130-131), and in Washington and southern Vancouver Island, of 157 radio-tagged birds, four produced fledglings (Lorenz et al. 2017, p. 312). If we assume (as in Peery et al. 2004, p. 1094) that 93 percent of captured birds in each sample were of breeding age, and that half of all captured birds and half of all fledged chicks were female, fecundity rates from these samples would be 0.027 in Washington, and between 0.021 and 0.063 in northern California.

Unadjusted and adjusted values for estimates of marbled murrelet juvenile ratios also suggest low reproductive rates. In northern California and Oregon, annual estimates for $\acute{R}$ range from 0 to 0.140, depending on the area surveyed (Strong 2014, p. 20; Strong 2015, p. 6; Strong 2016, p. 7; Strong 2017, p. 6; Strong 2018, p. 7; Strong 2019, p. 6; Strong and Falxa 2012, p. 4). In Conservation Zone 4, the annual average between 2000 and 2011 was 0.046 (Strong and Falxa 2012, p. 11). In central California, estimates of $\acute{R}$ range from 0 to 0.12, with an annual average of 0.048, over 21 years of survey between 1996 and 2019 (Felis et al. 2020, p. 9). An independent calculation of $\acute{R}$ among marbled murrelets captured in central California between 1999 and 2003 resulted in estimates ranging from 0 to 0.111, with an average of 0.037 (Peery et al. 2007, p. 235). Estimates for $\acute{R}$ in the San Juan Islands in Washington tend to be higher, ranging from 0.02 to 0.12, with an average of 0.067, over 18 years of survey between 1995 and 2012 (Lorenz and Raphael 2018, pp. 206, 211). Notably, $\acute{R}$ in the San Juan Islands did not show any temporal trend over the 18-year period, even while the abundance of adult and subadult marbled murrelets declined (Lorenz and Raphael 2018, pp. 210-211).

Although these estimates of $\acute{R}$ are higher than one would expect based on fecundity rates derived from radio-telemetry studies, they are below the level thought to be necessary to maintain or increase the marbled murrelet population. Demographic modeling, historical records, and comparisons with similar species all suggest that marbled murrelet population stability requires juvenile ratios between 0.176 and 0.3 (Beissinger and Peery 2007, p. 302; USFWS 1997, p. B-13). Even the lower end of this range is higher than any current estimate for $\acute{R}$ for any of the Conservation Zones. This indicates that the marbled murrelet reproductive rate is likely insufficient to maintain stable population numbers throughout all or portions of the species' listed range. These sustained low reproductive rates appear to be at odds with the potentially stable population size measured for Zones 1 through 5 and are especially confusing in light of apparent population increases in Oregon and California. However, the populations of birds that breed in each zone (which, by all measures of productivity, we would expect to be shrinking throughout the range) is not necessarily the same thing as the numbers of birds at sea. This issue is discussed further in the section below.

Integration and Summary: Marbled murrelet Abundance, Distribution, Trend, and Reproduction

A statistically significant decline was detected in Conservation Zones 1 and 2 for the 2001-2019 period (Table 2). The overall population trend from the combined 2001-2019 population estimates (Conservation Zones 1 - 5) indicates a potentially stable population with a 0.5 percent increase per year (McIver et al. 2021, p. 4). Because the confidence intervals for this estimate are fairly tight around 0, there is not clear evidence of either or a positive or negative trend. At the state-scale, significant declines have occurred in Washington, while subpopulations in Oregon and California show a statistically meaningful increase (McIver et al. 2021, p. 4).

The current ranges of estimates for fecundity and for $\dot{R}$, the juvenile to adult ratio, are below the level assumed to be necessary to maintain or increase the marbled murrelet population. Whether derived from radio-telemetry, marine surveys or from population modeling ($\dot{R}$ = 0.02 to 0.13, Table 4), the available information is in general agreement that the current ratio of hatch-year birds to after-hatch year birds is insufficient to maintain stable numbers of marbled murrelets throughout the listed range. The current estimates for $\dot{R}$ also appear to be well below what may have occurred prior to the marbled murrelet population decline (Beissinger and Peery 2007, p. 298).

The reported stability of the population at the larger scale (Zones 1 through 5) and growth of subpopulations in Oregon and California appear to be at odds with the sustained low reproductive rates reported throughout the listed range. A number of factors could contribute to this discrepancy. For example, population increases could be caused by an influx of marbled murrelets moving from the Canadian population into Oregon and California, or into Washington and displacing Washington birds to Oregon and California. The possibility of a population shift from Washington to Canada has previously been dismissed, based on nest-site fidelity and the fact that both Washington and British Columbia populations are declining simultaneously (Falxa et al. 2016, p. 30), but these arguments do not rule out the possibility that non-breeding marbled murrelets originating in Canada may be spending time foraging in Oregon or California waters.

Another possibility is the proportion of birds present on the water during surveys, rather than inland at nest sites, may be increasing. If so, this would artificially inflate population estimates. Such a shift could be driven by low nesting rates, as were observed in Oregon in 2017 (Adrean et al. 2018, p. 2; Horton et al. 2017, p. 77); or by shifts toward earlier breeding, for which there is anecdotal evidence (for example, Havron 2012, p. 4; Pearson 2018, in litt.; Strong 2019, p. 6); or a combination of both factors. In either case, individuals that would in earlier years have been incubating an egg or flying inland to feed young, and therefore unavailable to be counted, would now be present at sea and would be observed during surveys. For the same number of birds in the population, the population estimate would increase as adults spend more of the survey period at sea.

Finally, the shift that occurred in 2015 to sampling only half of the Conservation Zones in each survey year (McIver et al. 2021, pp. 5-6) is increasing the uncertainty in how to interpret the survey results, especially in light of large-scale movements that can occur during the breeding season, sometimes involving numerous individuals (Horton et al. 2018, p. 77; Peery et al. 2008a, p. 116). Marbled murrelets that move into or out of the zone being sampled during the breeding season could artificially inflate or deflate the population estimates. Even interannual movements among the Zones could temporarily resemble population growth, without an actual increase in the number of birds in the population (McIver et al., in press, pp. 14, 43).

Some of these factors would also affect measures of fecundity and juvenile ratios. For example, if marbled murrelets are breeding earlier on average, then the date adjustments applied to juvenile ratios may be incorrect, possibly resulting in inflated estimates of $\dot{R}$. If current estimates of $\dot{R}$ are biased high, this would mean that the true estimates of $\dot{R}$ are even lower, exacerbating, rather than explaining, the discrepancy between the apparently sustained low reproductive rates and the apparently stable or increasing subpopulations south of Washington. A shift toward later breeding could result in more adults being present at sea during surveys, and would also result in artificially low estimates of $\dot{R}$. We are not aware of evidence for a widespread shift toward later breeding, but this kind of alteration in seasonal behavior may be more difficult to detect than a shift to earlier breeding. Early-fledging juveniles are conspicuous when observed at sea, whereas late-fledging juveniles are not.

Considering the best available data on abundance, distribution, population trend, and the low reproductive success of the species, the Service concludes the marbled murrelet population within the Washington portion of its listed range currently has little or no capability to self-regulate, as indicated by the significant, annual decline in abundance the species is currently undergoing in Conservation Zones 1 and 2. Populations in Oregon and California are apparently more stable, but reproductive rates remain low in those areas, and threats associated with habitat loss and habitat fragmentation continue to occur. The Service expects the species to continue to exhibit further reductions in distribution and abundance , due largely to the expectation that the variety of environmental stressors present in the marine and terrestrial environments (discussed in the *Threats to Marbled murrelet Survival and Recovery* section) will continue into the foreseeable future.

Threats to Marbled murrelet Survival and Recovery

When the marbled murrelet was listed under the Endangered Species Act in 1992, several anthropogenic threats were identified as having caused the dramatic decline in the species:

- Habitat destruction and modification in the terrestrial environment from timber harvest and human development caused a severe reduction in the amount of nesting habitat.
- Unnaturally high levels of predation resulting from forest "edge effects".
- The existing regulatory mechanisms, such as land management plans (in 1992), were considered inadequate to ensure protection of the remaining nesting habitat and reestablishment of future nesting habitat.
- Manmade factors such as mortality from oil spills and entanglement in fishing nets used in gill-net fisheries.

The regulatory mechanisms implemented since 1992 that affect land management in Washington, Oregon, and California (for example, the NWFP) and new gill-netting regulations in northern California and Washington have reduced the threats to marbled murrelets (USFWS 2004, pp. 11-12). However, additional threats were identified, and more information was compiled regarding existing threats, in the Service's 5-year reviews for the marbled murrelet compiled in 2009 and 2019 (USFWS 2009, pp. 27-67; USFWS 2019, pp. 19-65). These stressors are related to environmental factors affecting marbled murrelets in the marine and terrestrial environments. These stressors include:

- Habitat destruction, modification, or curtailment of the marine environmental conditions necessary to support marbled murrelets due to:
  - Elevated levels of toxic contaminants, including polychlorinated biphenyls, polybrominated diphenyl ether, polycyclic aromatic hydrocarbons, and organochlorine pesticides, in marbled murrelet prey species.
  - The presence of microplastics in marbled murrelet prey species.
  - Changes in prey abundance and availability.
  - Changes in prey quality.
  - Harmful algal blooms that produce biotoxins leading to domoic acid and paralytic shellfish poisoning that have caused marbled murrelet mortality.
  - Harmful algal blooms that produce a proteinaceous foam that has fouled the feathers of other alcid species and affected areas of marbled murrelet marine habitat.
  - Hypoxic or anoxic events in marbled murrelet marine habitat.
  - Climate change in the Pacific Northwest.
- Manmade factors that affect the continued existence of the species include:
  - Derelict fishing gear leading to mortality from entanglement.
  - Disturbance in the marine environment (from exposures to lethal and sub-lethal levels of high underwater sound pressures caused by pile-driving, underwater detonations, and potential disturbance from high vessel traffic).
  - Wind energy generation, currently limited to onshore projects, leading to mortality from collisions.

Since the time of listing, some marbled murrelet subpopulations have continued to decline due to lack of successful reproduction and recruitment, and while other subpopulations appear to be stable or increasing, productivity in these populations remains lower than the levels likely to support sustained population stability. The marbled murrelet Recovery Implementation Team identified five major mechanisms that appear to be contributing to poor demographic performance (USFWS 2012b, pp. 10-11):

- Ongoing and historic loss of nesting habitat.
- Predation on marbled murrelet eggs and chicks in their nests.
- Changes in marine conditions, affecting the abundance, distribution, and quality of marbled murrelet prey species.
- Post-fledging mortality (predation, gillnets, oil-spills).
- Cumulative and interactive effects of factors on individuals and populations.

Climate Change

In the Pacific Northwest, climate change affects both the marine and forested environments on which marbled murrelets depend. Changes in the terrestrial environment may have a direct effect on marbled murrelet reproduction, and also affect the structure and availability of nesting habitat. Changes in the marine environment affect marbled murrelet food resources. Changes in either location may affect the likelihood, success, and timing of marbled murrelet breeding in any given year.

Changes in the Physical Environment

Projected changes to the climate within the range of the marbled murrelet include air and sea surface temperature increases, changes in precipitation seasonality, and increases in the frequency and intensity of extreme rainfall events (Mauger et al. 2015, pp. 2-1 – 2-18; Mote and Salathé 2010, p. 29; Salathé et al. 2010, pp. 72-73). Air temperature warming is already underway, and is expected to continue, with the mid-21st century projected to be approximately four to six degrees Fahrenheit (°F) (2.2 to 3.3 degrees Celsius [°C]) warmer than the late 20th century (Mauger et al. 2015, p. 2-5; USGCRP 2017, pp. 196-197). Similarly, sea surface temperatures are already rising and the warming is expected to continue, with increases between 2.2 °F (1.2 °C) and 5.4 °F (3 °C) projected for Puget Sound, the Strait of Georgia, and the Pacific Coast between the late 20th century and mid-or late-21st century (Mote and Salathé 2010, p. 16; Riche et al. 2014, p. 41; USGCRP 2017, p. 368). Summer precipitation is expected to decrease, while winter precipitation is expected to increase (Mauger et al. 2015, p. 2-7; USGCRP 2017, p. 217). In particular, heavy rainfall events are projected to occur between two and three times as frequently and to be between 19 and 40 percent more intense, on average, in the late 21st century than they were during the late 20th century (Warner et al. 2015, pp. 123-124).

The warming trend and trends in rainfall may be masked by naturally-occurring climate cycles, such as the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) (Reeder et al. 2013, p. 76). These oscillations have similar effects in the Pacific Northwest, with relatively warm coastal water and warm, dry winter conditions during a "positive" warm phase, followed by cooler coastal water and cooler, wetter winter conditions during the cool "negative" phase (Moore et al. 2008, p. 1747). They differ in that one phase of the ENSO cycle typically lasts between 6 and 18 months (one to three years for a full cycle), whereas, during the 20th century, each phase of the PDO cycle lasted approximately 20 to 30 years (approximately 40 to 60 years for a full cycle) (Mantua and Hare 2002, p. 36). Some studies break the PDO into two components, one with a full cycle length between 16 and 20 years and the other with a 50 to 70-year period, with the longer component referred to as the Pacific Multidecadal Oscillation (PMO) (Steinman et al. 2015, p. 988). Another recent study has identified a 60-year cycle separate from the longer-term component of the PDO, also referring to this as the PMO (Chen et al. 2016, p. 319). An additional pattern, the North Pacific Gyre Oscillation, is associated with changes in the alongshore winds that drive upwelling and appears to complete approximately one cycle per decade (Di Lorenzo et al. 2008, pp. 2-3).

The overall warming projections described above for the listed range of the marbled murrelet will be superimposed over the natural climate oscillations. The climate models used to project future trends account for naturally occurring cycles (IPCC 2014, p. 56). Therefore, the projected trend combined with the existing cycles mean that temperatures during a cool phase will be less cool than they would be without climate change, and warm phases will be warmer. During the winter of 2014-2015, the climate shifted from a negative cool phase of the PDO to a positive warm phase (Peterson et al. 2016, p. 46). Additionally, one study predicts that the PMO will enter a positive warm phase around the year 2025 (Chen et al. 2016, p. 322). The phases of these long-term climate cycles in addition to the projected warming trend imply that we should expect sea surface temperatures during the period over the next couple of decades to be especially warm. However, climate change may also alter the patterns of these oscillations, for example, by shortening the cycle length of the PDO (Zhang and Delworth 2016, pp. 6007-6008). Many studies of climate effects to marine species and ecosystems use indices of these climate oscillations, rather than individual climate variables such as sea surface temperature, as their measures of the climatic state (e.g. Becker and Beissenger 2006, p. 473). Therefore, if climate factors that covary with a given oscillation become decoupled, the relationships inferred from these studies may no longer be valid in the future.

Changes in the Forest Environment

Forested habitats in the Pacific Northwest are affected by climate change mainly via changes in disturbances, including wildfire, insects, tree diseases, and drought mortality. These types of disturbances can all cause the loss of marbled murrelet nesting habitat, though it is hoped that this loss will be offset by ingrowth as existing mid-successional forest matures. Following stand-replacing disturbances, climate conditions may not allow recruitment of the tree species that are currently present, leading to ecotype change; however, the effect of this kind of ecotype change may not directly affect marbled murrelet habitat availability until many decades in the future.

Historical fire regimes have varied throughout the range of the marbled murrelet. In many of the moist forests of western Washington and Oregon, the fire regime has historically been typified by large, stand-replacing fires occurring at intervals of 200 years or more (Halofsky et al. 2018a, pp. 3-4; Haugo et al. 2019, pp. 2-3; Long et al. 1998, p. 784). Parts of the marbled murrelet range in southern Oregon and California have historically had low- and mixed-severity fires occurring every 35 years or less (Haugo et al. 2019, pp. 2-3; Perry et al. 2011, p. 707). Still other areas throughout the range historically had mixed severity fires occurring between 35 and 200 years apart (Haugo et al. 2019, pp. 2-3; Perry et al. 2011, p. 707). Within each type of historical fire regime, fire has occurred less frequently during the recent decades usually used for statistical analyses of fire behavior or projections of future fire than it did historically (Huago et al. 2019, pp. 8-9; Littell et al. 2010, p. 150).

Between 1993 and 2012, monitoring based on a database of large (1,000 acres or greater) fire perimeters detected losses associated with wildfires of 22,063 acres of Maxent-modeled high-quality marbled murrelet nesting habitat on federal and non-federal lands in the NWFP area (Raphael et al. 2016b, pp. 80-81). Fire was the leading natural cause of habitat loss within the NWFP area, but this ranking was driven by the 20,235-acre loss to fire on federal lands in the Klamath Mountains, and fire was far less important elsewhere in the range. Within subregions overlapping the listed range of the marbled murrelet, the proportion of area currently "highly suitable" for large fires varies from less than 1 percent in the Coast Range of Oregon and Washington to 18 percent in the Klamath Mountains (Davis et al. 2017, p. 179). The fire regime in the listed range of the marbled murrelet has historically been sensitive to climate conditions, though less so during recent decades (Henderson et al. 1989, pp. 13-19; Littell et al. 2010, p. 140; Littell and Gwozdz 2011, pp. 130-131; Weisberg and Swanson 2003, pp. 23-25). South of the NWFP area, extreme heat and unusual lightning activity contributed to the 2020 fires that burned through much of the remaining marbled murrelet habitat in central California, and these conditions were likely caused or exacerbated by climate change (Goss et al. 2020, p. 11; Mulkern 2020, pp. 2, 5-6; Romps et al. 2014, p. 853; Temple 2020, p. 2).

The area burned in the range of the marbled murrelet is expected to increase in the coming decades, but there is great uncertainty about the magnitude of the increase, and it is likely to affect some areas more than others (Davis et al. 2017, pp. 179-182; Rogers et al. 2011, p. 6; Sheehan et al. 2015, p. 25). On forested lands in the Cascades, Coast Ranges, and Klamath Mountains of Washington and Oregon, the percentage of forested area highly suitable for large fires is projected to increase from the current (less than 1 percent to 18 percent, varying by ecoregion) up to between 2 and 51 percent by the late 21st century, with much of this increase projected to occur after 2050 (Davis et al. 2017, pp. 179-181). At the same time, the percentage of forested lands with low suitability for large fire is expected to decrease from the current range of 21 to 97 percent to a lower range of 4 to 85 percent, depending on ecoregion. The increase in large fire suitability is expected to have the greatest effect on the Klamath ecoregion and the smallest effect on the Coast Ranges, with Cascades ecoregions falling in between (Davis et al. 2017, pp. 181). One study has classified most of the marbled murrelet range as having low vulnerability to fire for the 2020-2050 period, relative to all western forests, but parts of the range in southern Oregon and northern California are classified as having medium or high vulnerability (Buotte et al. 2018, pp. 5, 8). A different study found that forests west of the Cascade Crest are likely to be more vulnerable other western forests, because they will be sensitive to hotter, drier summers, but will not benefit from increased winter precipitation since soils are already saturated during winter months (Rogers et al. 2011, p. 6). Throughout the range, the annual number of days with high wildfire potential is expected to nearly double by mid-century (Martinuzzi et al. 2019, pp. 3, 6). Fire severity is also projected to increase over the 21st century (Rogers et al. 2011, p. 6).

Two recent studies have modeled future fires based on projected climate and vegetation characteristics, rather than simply using statistical projections based on past rates of wildfire. One study projected a 1.5- to 5-fold increase in forest fire in western Washington between the historical period and the 21st century (Halofsky et al. 2018b, p. 10). The baseline annual percentage of area burned was based on information about pre-European settlement fire rotation in western Washington, 0.2 to 0.3 percent of the forest land base burned per year, which is a much greater annual area burned than we have observed in the recent past. The late 21st-century annual area burned was projected to reach 0.3 to 1.5 percent of the forest land base per year, with extreme fire years burning 5 to 30 percent of the forest land base (Halofsky et al. 2018b, p. 10). The other study projected a 2- to 4-fold increase in western Washington and Oregon between the late 20th century and mid-century (Sheehan et al. 2019, p. 14). This study started with even larger baseline annual percentage of area burned, starting at 0.47 to 0.56 percent per year in the late 20th century and increasing to 1.14 to 1.99 percent per year by the mid-21st century (Sheehan et al. 2019, p. 14). In both studies, smaller increases in annual area burned were associated with a model assumption that firefighting would continue to be effective.

Insects and disease were the leading natural cause of marbled murrelet habitat loss within most ecoregions within the NWFP area between 1993 and 2012 (Raphael et al. 2016b, p. 81). Across the NWFP area, 8,765 acres of Maxent-modeled high-quality marbled murrelet habitat were lost to insects and disease, with the majority of these on federal lands in Washington. The USFS and WDNR have worked together since 1981 to collect and distribute aerial survey data regarding the presence of insects, disease, and other damage agents in Washington's forests (WDNR and USFS 2018). This dataset indicates the identity of various insect and disease problems that have been recorded in the current marbled murrelet habitat: Douglas-fir beetle (*Dendroctonus pseudotsugae*), "dying hemlock," fir engraver (*Scolytus ventralis*), spruce aphid (*Elatobium abietinum*), Swiss needle cast (*Phaeocryptopus gaeumannii*), and western (*Lambdina fiscellaria lugubrosa*) and phantom (*Nepytia phantasmaria*) hemlock loopers. It is likely that various root diseases have also attacked marbled murrelet habitat, but these are generally classified as bear damage during the aerial surveys (Clark et al. 2018, p. 31). Root diseases that may be present include annosus (*Heterobasidium annosum*), armillaria (*Armillaria ostoyae*), and black stain (*Leptographium wageneri*) root diseases, as well as laminated (*Phellinus weirii*), tomentosus (*Inonotus tomentosus*), and yellow (*Parenniporia subacida*) root rots (Goheen and Willhite 2006, pp. 72-87).

Some of these pests, such as Swiss needle cast, are most typically found in younger stands, and are more likely to affect the development of marbled murrelet habitat over the long term; whereas others, such as Douglas-fir beetle, are more likely to attack older trees (Goheen and Willhite 2006, pp. 30, 224). Swiss needle cast typically does not result in tree mortality (Maguire et al. 2011, pp. 2069-2070), but can affect mixed-species forest stands by allowing increased western hemlock growth in stands where severe Swiss needle cast affects Douglas-fir growth (Zhao et al. 2014, entire). Higher average temperatures, in particular warmer winters, and increased spring precipitation in the Oregon Coast Range have contributed to an increase in the severity and distribution of Swiss needle cast in Douglas-fir (Stone et al. 2008, pp. 171-174; Sturrock et al. 2011, p. 138; Zhao et al. 2011, p. 1,876; Lee et al. 2013, pp. 683-685; Ritóková et al. 2016, p. 2). The distribution of Swiss needle cast increased from about 131,087 ac (53,050 ha) in 1996 to about 589,840 ac (238,705 ha) of affected trees in 2015 within 31 mi (50 km) of the coast in the Oregon Coast Range (Hansen et al. 2000, p. 775; Ritóková et al. 2016, p. 5).

Drought has not historically been a major factor in most of the listed range of the marbled murrelet, because these forests are not typically water limited, especially in Washington and northern Oregon (Littell et al. 2010, p. 139; McKenzie et al. 2001, p. 531; Nemani et al. 2003, p. 1560). Nonetheless, every part of the listed range has been affected by multi-year drought at some point during the 1918-2014 period, varying geographically from areas with occasional mild two- to five-year droughts, to areas with moderate-severity two- or three-year droughts, to a few small areas, all in Washington, that have had at least one extreme three-year drought (Crockett and Westerling 2018, p. 345). Over the last few decades, the number of rainy summer days has decreased, and the rain-free period has lengthened in much of the marbled murrelet's listed range, especially in Oregon and Washington (Holden et al. 2018, p. 4). In the Pacific Northwest generally, drought is associated with Douglas-fir canopy declines that can be observed via satellite imagery (Bell et al. 2018a, pp. 7-10). In Western Washington, Oregon, and Southwestern British Columbia, tree mortality more than doubled (from around 0.5 percent per year to more than 1 percent per year) over the 30-year period between 1975 and 2005, likely due to increasing water stress (van Mantgem et al. 2009, pp. 522-523). Tree mortality may be caused by warm dry conditions in and of themselves (via xylem failure) or when hot, dry conditions compound the effects of insects, disease, and fire.

Some of the insects and pathogens already present in marbled murrelet habitat, such as Douglas-fir beetles, are likely to become more prevalent and cause greater mortality in the future. Douglas-fir trees stressed by heat and drought emit ethanol, which attracts Douglas-fir beetles, and have lowered chemical defenses, which is likely to increase the endemic levels of Douglas-fir infestation and could result in higher probability of epidemic infestation (Agne et al. 2018, p. 326-327; Bentz et al. 2010, p. 605). Similarly, higher temperatures as the 21st century progresses will also increase the potential of spruce beetle (*Dendroctonus rufipennis*) outbreaks, which require mature spruce forests such as those found within the range of the marbled murrelet (Bentz et al. 2010, p. 607). There is more uncertainty with respect to future levels of infection by

Swiss needle cast, a disease that that has increased in severity over the past decade (Agne et al. 2018, p. 326). Warm, wet spring weather is thought to provide ideal conditions for Swiss needle cast infection, whereas warm, dry spring weather may inhibit the pathogen. Future spring weather will be warmer, but it is not clear whether it will be wetter, drier, or both (i.e., more variable), or perhaps current precipitation patterns will continue. Swiss needle cast effects to trees appear to be more severe during drought conditions, however. Therefore, the worst-case scenario for Swiss needle cast would be warm, wet springs followed by hot, dry summers. Swiss needle cast is also expected to spread inland and north to sites where fungal growth is currently limited by cold winter temperatures (Stone et al. 2008, p. 174; Zhao et al. 2011, p. 1,884; Lee et al. 2013, p. 688). Future climate conditions are also hypothesized to promote other diseases, such as Armillaria root disease, that could affect marbled murrelet habitat (Agne et al. 2018, p. 326).

All climate models project increased summer warming for the Pacific Northwest, and most project decreased spring snowpack and summer precipitation, resulting in increasing demand on smaller amounts of soil water in the forest during the growing season. Forests within the marbled murrelet range are expected to experience increasing water deficits over the 21st century (McKenzie and Littell 2017, pp. 33-34). These deficits will not be uniform, with the California and southern Oregon Coast Ranges, Klamath region, eastern Olympic Peninsula, and parts of the Cascades and northern Oregon Coast Range projected to experience much greater hydrological drought, starting sooner than in other places, while there are even projected reductions in water deficit for some other portions of the Washington Cascades and Olympic Mountains (McKenzie and Littell 2017, p. 31). Spring droughts, specifically, are projected to decrease in frequency in Washington and most of Oregon, but to increase in frequency in most of California, with some uncertainty as to the future likelihood of spring drought near the Oregon-California border (Martinuzzi et al. 2019, p. 6). The projected future warm, dry conditions sometimes called "hotter drought" or "climate change-type drought" in the scientific literature, are expected to lead to continued increases in tree mortality. Though projections of future drought-related tree mortality in throughout the listed range of the marbled murrelet are not available, the effects of the recent multi-year drought in the Sierra Nevada may provide some context about what to expect. Drought conditions in California during 2012 through 2015 led to an order of magnitude increase in tree mortality in Sierra Nevada forests (Young et al. 2017, p. 83). More mesic regions, including most areas of marbled murrelet habitat, are unlikely to have near-future impacts as severe as those already seen in the Sierra Nevada. For example, redwood forests in northwestern and central California, which include areas of marbled murrelet nesting habitat, are more resistant to drought effects than other California forests (Brodrick et al. 2019, pp. 2757-2758). However, extreme climate conditions are eventually likely to further increase drought stress and tree mortality, especially since trees in moist forests are unlikely to be well-adapted to drought stress (Allen et al. 2010, p. 669; Allen et al. 2015, pp. 19-21; Anderegg et al. 2013, p. 705; Crockett and Westerling 2018, p. 342; Prestemon and Kruger 2016, p. 262; Vose et al. 2016, p. 10).

Blowdown is another forest disturbance that has historically caused extensive stand-replacing disturbances in the Pacific Northwest. The effect of climate change on blowdown frequency, extent, and severity is unknown, and there are reasons to believe that blowdowns may become either more or less frequent or extensive. Blowdown events are often associated with extra-tropical cyclones, which are often associated with atmospheric rivers. Blowdown is influenced by wind speeds and by soil saturation. Hurricane-force winds hit the Washington coast approximately every 20 years during the 20th century (Henderson et al. 1989, p. 20). Destructive windstorms have occurred in the Pacific Northwest in 1780-1788, 1880, 1895, 1921, 1923, 1955, 1961, 1962, 1979, 1981, 1993, 1995, and 2006 (Henderson et al. 1989, p. 20; Mass and Dotson 2010, pp. 2500-2504). During the 20th century, the events in 1921, 1962, and 2006 were particularly extreme. Although there are some estimates of timber losses from these events, there are no readily available estimates of total marbled murrelet habitat loss from particular events. In addition to habitat loss from these extreme blowdown events, a smaller amount of habitat is lost each year in "endemic" blowdown events. Wind damage may be difficult to detect via methods that rely on remotely sensed data (e.g., Raphael et al. 2016b, pp. 80-81) because much of the wind-damaged timber may be salvaged, and therefore appears to have been disturbed by harvest rather than wind. Nonetheless, between 1993 and 2012, 3,654 acres of Maxent-modeled higher suitability nesting habitat loss was detected via remote sensing and attributed to blowdown or other natural, non-fire, non-insect disturbances (Raphael et al. 2016b, pp. 80-81). Nearly all of the habitat loss in this category affected federal lands in Washington.

Because we did not locate any studies attempting to project marbled murrelet habitat loss to blowdown into the future, we looked to studies regarding the conditions associated with blowdown: wind, rain, and landscape configuration. There are indications that average wind speeds over the Pacific Northwest have declined since 1950, and average wind speeds are projected in most climate models to decline further by the 2080s (Luce et al. 2013, pp. 1361-1362). However, it is not clear how average wind speeds might be related to blowdown since blowdown events usually happen during extreme wind events. Extreme extra-tropical cyclones are expected to become less frequent in the Northern Hemisphere in general, and perhaps along the Pacific Northwest coastline in particular, but these predictions involve many uncertainties. Different models show local increases in storm frequency in different places (Catto et al. 2011, pp. 5344-5345). Also, how "extreme" events are categorized differs between studies, and the results vary depending on what definition of "extreme" is used (Catto et al. 2001, p. 5348; Ulbrich et al. 2009, p. 127). One recent model projects no change in the extreme ground-level winds most likely to damage nesting habitat, and an increase in the frequency of extreme high-altitude winds (Chang 2018, pp. 6531, 6539). Atmospheric rivers are expected to become wetter and probably more frequent. The frequency of atmospheric river days is expected to increase by 50 to around 500 percent over the 21st century, depending on latitude and season (Gao et al. 2015, p. 7182; Warner and Mass 2017, p. 2135), though some models project up to an 18 percent decrease in frequency for either the northern or the southern end of the listed range (Payne and Magnusdottir 2015, p. 11,184). The most extreme precipitation events are expected to be between 19 and 40 percent wetter, with the largest increases along the northern California coast (Warner et al. 2015, p. 123). If increased rain causes greater soil saturation, it is easily conceivable that blowdown would become likely at lower wind speeds than would be needed to cause blowdown in less saturated conditions, but we did not find studies addressing this relationship. Since blowdown is more likely at forest edges, increased fragmentation may lead to more blowdown for the same wind speed and amount of soil saturation. The proportion of Maxent-modeled higher suitability nesting habitat located along forest edges increased between 1993 and 2012, and now makes up the majority of habitat in the NWFP area (Raphael et al. 2016b, p. 77). Some forested areas within the range may become less fragmented over the next 30 years, as conservation plans such as the NWFP continue to allow for forest growth; other areas may become more fragmented due to harvest, development, or the forest disturbances discussed above. Thus, the amount of marbled murrelet habitat likely to be lost to blowdown over the next 30 years is highly uncertain.

Synergistic effects between drought, disease, fire, and/or blowdown are likely to occur to some extent and could become widespread. If large increases in mortality do occur, interactions between these agents are likely to be involved (Halofsky et al. 2018a, pp. 4-5). The large recent increase in tree mortality in the Sierra Nevada has been caused in large part due to these kinds of synergistic interactions. As noted above, range of the marbled murrelet is unlikely to be as severely affected and severe effects are likely to happen later in time here than drier forests (where such effects are already occurring). In fact, one study rates much of the range as having low vulnerability, relative to other western forests, to drought or fire effects by 2049 (Buotte et al. 2018, p. 8). However, that study and many other studies do indicate that there is a risk of one or more of these factors acting to cause the loss of some amount of marbled murrelet habitat over the next 30 years.

In addition to habitat loss resulting from forest disturbances at the scale of a stand or patch, habitat features may be altered as a result of climate change. For example, epiphyte cover on tree branches may change as a result of the warmer, drier summers projected for the future (Aubrey et al. 2013, p. 743). Climate-related changes in epiphyte cover will be additive or synergistic to changes in epiphyte cover resulting from the creation of forest edges through timber harvest (Van Rooyen et al. 2011, pp. 555-556). Epiphyte cover is assumed to have decreased throughout the listed range as the proportion of suitable habitat in edge condition has increased (USFWS 2019, p. 34), and as epiphyte cover decreases further, nest sites will become less available even in otherwise apparently suitable habitat.

In summary, forest disturbances, including wildfire, insect damage, disease, drought mortality, and windthrow, are likely to continue to remove marbled murrelet nesting habitat, and many of these disturbances are likely to remove increasing amounts of habitat in the future. The effects of each type of disturbance are likely to be variable in different parts of the range, with wildfire affecting the Klamath Mountains far more than other parts of the range, and insect and disease damage largely focused in Washington. The magnitude of future increases is highly uncertain, and it is unclear whether windthrow will increase, decrease, or remain constant. Habitat not lost to disturbance may nonetheless be affected by climate change, as particular habitat features may be lost. The effects of habitat loss and the loss of habitat features will reduce the availability of nesting habitat, which will reduce the potential for marbled murrelet reproduction.

<u>Changes in the Marine Environment</u>

Changes in the climate, including temperature changes, precipitation changes, and the release of carbon dioxide into the atmosphere, affect the physical properties of the marine environment, including water circulation, oxygen content, acidity, and nutrient availability. These changes, in turn, affect organisms throughout the marine food web. For top predators like the marbled murrelet, Prey abundance, quality, and availability are all likely to be affected by climate change. Climate change is also likely to change the marbled murrelet's level of exposure to toxic chemicals and potentially to disease agents. All of these changes are likely to alter the reproduction and survival of individual marbled murrelets.

Marine waters within the range of the marbled murrelet have warmed, as noted above. This warming involves not only a gradual increase in average temperatures, but also extreme marine heatwaves, which have dramatic effects on marine ecosystems. Preceding the development of El

Niño conditions in 2015, a rise in sea surface temperatures in the Gulf of Alaska occurred in late 2013, likely due to a shift in wind patterns, lack of winter storms, and an increase in sea-level pressure (Bond et al. 2015, p. 3414; Leising et al. 2015, pp. 36, 38, 61). This warm water anomaly expanded southward in 2014, with further warming along the California Current in 2015, and then merged with another anomaly that developed off Baja California, becoming the highest sea surface temperature anomaly observed since 1982 when measurements began (NMFS 2016, p. 5). These anomalies became known as "the Blob" (Bond et al. 2015, p. 3414) and helped to compress the zone of cold upwelled waters to the nearshore (NMFS 2016, p. 7). During the late summer of 2019, a new marine heatwave began developing, and is currently on a trajectory to be as extreme as the 2014-2015 "Blob" (NMFS 2019).

The marine portion of the listed range of the marbled murrelet is located along the California Current and estuary systems (including the Salish Sea) adjacent to it. The California Current is strongly influenced by upwelling, in which water rises from the deep ocean to the surface. Upwelling along the west coast leads to an influx of cold waters rich in nutrients such as nitrates, phosphates, and silicates, but that are also acidic (due to high dissolved carbon dioxide content) and low in dissolved oxygen (Johannessen et al. 2014, p. 220; Krembs 2012, p. 109; Riche et al. 2014, pp. 45-46, 48; Sutton et al. 2013, p. 7191). Changes in upwelling are likely to occur, and to influence the ecosystem components most important to marbled murrelets. If changes in upwelling occur along the outer coast of Washington, these changes will also affect the interchange of waters through the Strait of Juan de Fuca (Babson et al. 2006, p. 30; Newton et al. 2003, p. 718). It has been hypothesized that as climate change accentuates greater warming of air over land areas than of air over the ocean, alongshore winds will intensify, which will lead to an increase in upwelling (Bakun 1990, entire). Historical records show that these winds have intensified over the past several decades (Bylhower et al. 2013, p. 2572; García-Reyes and Largier 2010, p. 6; Sydeman et al. 2014, p. 78-79; Taboada et al. 2019, p. 95; Wang et al. 2015, pp. 390-391). Projections for future changes in upwelling offer some support for this hypothesis, but are more equivocal (Foreman et al. 2011, p. 10; Moore et al. 2015, p. 5; Mote and Mantua 2002, p. 53-3; Rykaczewski et al. 2015, pp. 6426-6427; Wang et al. 2010, pp. 263, 265). Some studies indicate a trend toward a later, shorter (but in some cases, more intense) upwelling season, though at the southern end of the range the season may be lengthening (Bograd et al. 2009, pp. 2-3; Bylhower et al. 2013, p. 2572; Diffenbaugh et al. 2004, p. 30; Foreman et al. 2011, p. 8; Garcia-Reyes and Largier 2010, p. 6). Trends and projections for the future of upwelling in the California Current may be so variable because upwelling is inherently difficult to model, or because upwelling in this region is heavily influenced by climate cycles such as the NPGO, PDO, and ENSO (Macias et al. 2012, pp. 4-5; Taboada et al. 2019, p. 95; Wang et al. 2015, p. 391).

Regardless of potential changes in the timing or intensity of upwelling, the dissolved oxygen content of the waters in the listed range is expected to decrease. The solubility of oxygen in water decreases with increasing temperature, so as the climate becomes warmer, the dissolved oxygen content of the marine environment is expected to decrease (IPCC 2014, p. 62; Mauger et al. 2015, pp. 7-3, 7-8). The oxygen content in the North Pacific Ocean has declined significantly since measurements began in 1987 (Whitney et al. 2007, p. 184), and this decline is projected to continue (Whitney et al. 2013, p. 2204). Hypoxic and anoxic events, in which the lack of dissolved oxygen creates a dead zone, have occurred in Puget Sound and along the outer coasts of Washington and Oregon (PSEMP Marine Waters Workgroup 2017, p. 22; PSEMP Marine Waters Workgroup 2016, p. 15; Oregon State University 2017, entire). These dead zones have expanded into shallower depths and areas closer to shore, and impacts are expected to increase rapidly (Chan et al. 2016, p. 4; Somero et al. 2016, p. 15). If upwelling does increase in intensity, the effect would likely be to further reduce the oxygen content of nearshore waters, but these changes are not likely to be consistent throughout the region or throughout the year. Changes in oxygen content, or in the timing of low-oxygen periods, may have important biological consequences (see below). Oxygen content also responds to biological activity. In addition to climate change-induced effects, some locations will likely experience reductions in oxygen content stemming from biological responses to eutrophication in areas that receive (and do not quickly flush) nutrient inputs from human activities (Cope and Roberts 2013, pp. 20-23; Mackas and Harrison 1997, p. 14; Roberts et al. 2014, pp. 103-104, 108; Sutton et al. 2013, p. 7191).

Similarly, acidification of waters in the listed range is expected to increase, regardless of any changes in upwelling. Acidification results when carbon dioxide in the air dissolves in surface water, and is the direct consequence of increasing carbon dioxide emissions (IPCC 2014, pp. 41, 49). Marine waters are projected to continue becoming more acidic, and ocean acidification is now expected to be irreversible at human-relevant timescales (IPCC 2014, pp. 8-9, 49; IPCC 2019, pp. 1-4, 1-7, 1-14). Both the surface and upwelled waters of North Pacific Ocean have become more acidic due to carbon dioxide emissions (Feely et al. 2008, pp. 1491-1492, Murray et al. 2015, pp. 962-963), and this trend is expected to continue (Byrne et al. 2010, p. L02601; Feely et al. 2009, pp. 40-46). These waters also contribute to acidification Conservation Zone 1 as they flow in through the Strait of Juan de Fuca (Feely et al. 2010, p. 446, Murray et al. 2015, p. 961). Any increase in upwelling intensity or changes in seasonality would respectively increase acidification or change the timing of pH changes in the marbled murrelet range. It is unknown whether regional carbon dioxide emissions cause additional localized acidification within particular parts of the range (Newton et al. 2012, p. 36), but it is likely that other products of fossil fuel combustion, such as sulfuric acid, do contribute (Doney et al. 2007, pp. 14582-14583). Linked to reductions in dissolved oxygen (Riche et al. 2014, p. 49), acidification has important biological consequences (see below), and also responds to biological activity. For example, local areas of eutrophication are likely to experience additional acidification beyond that caused directly or indirectly by carbon dioxide emissions (Newton et al. 2012, pp. 32-33).

Sea level rise is also expected to affect the listed range of the marbled murrelet. Sea level rise is a consequence of the melting of glaciers and ice sheets combined with the expansion of water as it warms (IPCC 2014, p. 42). At regional and local scales, numerous factors affect sea level rise, including ocean currents, wind patterns, and plate tectonics (Mauger et al. 2015, p. 4-1; Dalrymple 2012, p. 81; Petersen et al. 2015, p. 21). Sea level is rising at most coastal locations in the action area (Mauger et al. 2015, p. 4-2; Dalrymple 2012, pp. 79-81; Shaw et al. 1998, p. 37). These increases in sea level are likely to continue and may accelerate in the near future (Bromirski et al. 2011, pp. 9-10; Dalrymple 2012, pp. 71, 102; Mauger et al. 2015, pp. 4-3 – 4-5; Mote et al. 2008, p. 10; Petersen et al. 2015, pp. 21, 29, and Appendix D). However, in some places, such as Neah Bay, Washington, plate tectonics are causing upward land movement that is currently outpacing sea level rise (Dalrymple 2012, p. 80; Montillet et al. 2018, p. 1204; Mote et al. 2008, pp. 7-8; Petersen et al. 2015, pp 24-26). In other places, sea-level rise is expected to have consequences for near-shore ecosystems (see below).

Physical Changes Specific to Conservation Zone 1

Conservation Zone 1 will be affected by changes in upwelling, dissolved oxygen content, and acidification discussed above, but these effects are expected to vary, both between Conservation Zone 1 and the other Zones, and within Zone 1, based on the exchange of waters through the Strait of Juan de Fuca and water circulation patterns within Zone 1. These water circulation patterns, in and of themselves, are expected to be affected by climate change. The complexity of the physical environment within Zone 1 can make some climate change effects difficult to predict.

Changes in temperature and the seasonality of precipitation over land affect the freshwater inflows to Conservation Zone 1. Spring and summer freshwater inflows are expected to be warmer and reduced in volume, whereas winter freshwater inflows are expected to increase (Lee and Hamlet 2011, p. 110; Mauger et al. 2015, p. 3-8; Moore et al. 2015, p. 6; Mote et al. 2003, p. 56). Many watersheds draining to the Salish Sea have historically been fed by a mix of rain and snowmelt, but are expected to be increasingly dominated by rainfall, which will cause the timing of peak flows to shift from spring to winter (Elsner et al. 2010, pp. 248-249; Hamlet et al. 2001, pp. 9-11; Hamlet et al. 2013, pp. 401-404; Mauger et al. 2015, pp. 3-4 – 3-5). With winter warming and increases in heavy rainfall events, flooding has increased, and this increase is expected to continue (Hamlet and Lettenmaier 2007, pp. 25-16; Lee and Hamlet 2011, p. 113; Mauger et al. 2015, pp. 3-6 – 3-7). Increased winter freshwater inflows, in combination with melting glaciers, are expected to bring increased sediments to the mouths of rivers; however, it is uncertain whether these sediments are more likely to enter the marine waters or to be deposited in estuaries (Czuba et al. 2011, p. 2; Lee and Hamlet 2011, pp. 129-134; Mauger et al. 2015, pp. 5-7 – 5-10).

These changes in seasonal freshwater inflows are expected to alter water circulation and stratification within Conservation Zone 1, and to affect the rate and timing of exchange of waters through the Strait of Juan de Fuca between the Puget Sound and the North Pacific Ocean (Babson et al. 2006, pp. 29-30; MacCready and Banas 2016, p. 13; Mauger et al. 2015, p. 6-2, Riche et al. 2014, pp. 37-39, 44-45, 49-50). This exchange occurs in two layers, with fresh water at the surface flowing toward the ocean, and denser, saltier ocean waters flowing from the ocean at greater depths (Babson et al. 2006, p. 30). With the projected changes in timing of freshwater inflows, the rate of exchange is expected to increase during winter and decrease during summer (Mauger et al. 2015, pp. 6-2 – 6-3). The effect of changes in freshwater inflow on stratification is likely to vary by location within the action area, with greater potential for effect in, for example, southern Puget Sound than in well-mixed channels like Admiralty Inlet and Dana Passage (Newton et al. 2003, p. 721).

When hypoxic (low dissolved oxygen) events occur in the waters of Zone 2, these waters also flow into the inland waters of Conservation Zone 1, driving down the oxygen content there as well, although there is considerable variation over time, space, and depth, due to patterns of circulation and mixing within the Salish Sea (Bassin et al. 2011, Section 3.2; Johannessen et al. 2014, pp. 214-220). For example, Hood Canal is particularly susceptible to hypoxic conditions, partly because circulation of water through Hood Canal is slow (Babson et al. 2006, p. 30), whereas the vigorous tidal currents in Haro Strait allow for the mixing of oxygen-rich surface water throughout the water column (Johannessen et al. 2014, p. 216). Increased stratification, as is expected during winter with the larger freshwater inflows, can lead to hypoxic conditions in deeper waters (Mauger et al. 2015, p. 6-3; Whitney et al. 2007, p. 189). On the other hand, weaker stratification, as expected in the summer, may decrease the probability of low oxygen due to greater mixing, or increase the probability of low oxygen due to slower circulation (Newton et al. 2003, p. 725).

Primary Productivity - Changes in temperature, carbon dioxide, and nutrient levels are likely to affect primary productivity by phytoplankton, macroalgae, kelp, eelgrass, and other marine photosynthesizers (IPCC 2019, p. 5-72; Mauger et al. 2015, p. 11-5). In general, warmer temperatures, higher carbon dioxide concentrations, and higher nutrient levels lead to greater productivity (Gao and Campbell 2014, pp. 451, 454; Nagelkerken and Connell 2015, p. 13273; Newton and Van Voorhis 2002, p. 10; Roberts et al. 2014, pp. 11, 22, 108; Thom 1996, pp. 386-387), but these effects vary by species and other environmental conditions, such as sunlight levels or the ratios of different nutrients (Gao and Campbell 2014, pp. 451, 454; Krembs 2012, p. 109; Kroeker et al. 2013, p. 1889; Low-Decarie et al. 2011, p. 2530). In particular, phytoplankton species that form calcium carbonate shells, such as coccolithophores, show weaker shell formation and alter their physiology in response to acidification, and are expected to decline in abundance with continued acidification (Feely et al. 2004, pp. 365-366; IPCC 2019, p. 5-62; Kendall 2015, pp. 26-46). Due to changes in the seasonality of nutrient flows associated with upwelling and freshwater inputs, there may also be alterations in the timing, location, and species composition of bursts of primary productivity, for example, earlier phytoplankton blooms (Allen and Wolfe 2013, pp. 6, 8-9; MacCready and Banas 2016, p. 17; Mauger et al. 2015, p. 6-3). Changes in primary productivity may not occur in every season; for example, during winter, sunlight is the major limiting factor through most of Conservation Zone 1 (Newton and Van Voorhis 2002, pp. 9, 12), and it is not clear whether winter sunlight is likely to change with climate change. Models project reductions in overall annual marine net primary productivity in the world's oceans during the 21st century, trends will vary across the listed marbled murrelet range, with decreases at the southern end of the range and increases at the northern end (IPCC 2019, pp. 5-31, 5-38). Changes in primary productivity are also likely to vary at smaller scales, even within a Conservation Zone; for example, primary productivity in Possession Sound is more sensitive to nutrient inputs than other areas within Puget Sound (Newton and Van Voorhis 2002, pp. 10-11). In sum, in addition to localized increases and decreases in productivity, we expect changes in the timing, location, and species dominance of primary producers.

Eelgrass (*Zostera marina*) is a particularly important primary producer in some parts of the range. In some areas, such as Padilla Bay in Zone 1, sea level rise is expected to lead to larger areas of suitable depth for eelgrass meadows. In such areas, eelgrass cover, biomass, and net primary production are projected to increase during the next 20 years (Kairis 2008, pp. 92-102), but these effects will depend on the current and future topography of the tidal flats in a given area. In addition, increasing dissolved carbon dioxide concentrations are associated with increased eelgrass photosynthetic rates and resistance to disease (Groner et al. 2018, p. 1807; Short and Neckles 1999, pp. 184-186; Thom 1996, pp. 385-386). However, increasing temperatures are not likely to be beneficial for eelgrass, and in combination with increased nutrients, could favor algal competitors (Short and Neckles 1999, pp. 172, 174; Thom et al. 2014, p. 4). Changes in upwelling are likely to influence eelgrass productivity and competitive interactions in small estuaries along the California Current (Hayduk et al. 2019, pp. 1128-1131). Between 1999 and 2013, eelgrass growth rates in Sequim Bay and Willapa Bay increased, but at a site in central Puget Sound, shoot density over a similar time period was too variable to detect trends (Thom et al. 2014, pp. 5-6). Taken together, these studies indicate that climate change may benefit eelgrass over the coming decades, but these benefits may be limited to specific areas, and negative effects may dominate in other areas (Thom et al. 2014, pp. 7-9).

Kelp forests also make important contributions to primary productivity in some parts of the range. Like eelgrass, bull kelp (*Nereocystis luetkeana*) responds to higher carbon dioxide concentrations with greater productivity (Thom 1996, pp. 385-386). On the other hand, kelp forests are sensitive to high temperatures (IPCC 2019, p. 5-72), and warming waters (among other factors) have reduced the range of giant kelp (*Macrocystis pyrifera* [Agardh]) (Edwards and Estes 2006, pp. 79, 85; Ling 2008, p. 892). In central and northern California, kelp forests have declined, but not along Oregon, Washington, and Vancouver Island (Krumhansl et al. 2016, p. 13787; Wernberg et al. 2019, p. 69). Along Washington's outer coast and the Strait of Juan de Fuca, bull kelp and giant kelp canopy area did not change substantially over the 20th century, though a few kelp beds have been lost (Pfister et al. 2018, pp. 1527-1528). In southern Puget Sound, bull kelp declines were observed between 2013 and 2017-2018, likely resulting from increasing temperature along with decreasing nutrient concentrations, suspended sediment, and the presence of parasites and herbivores (Berry et al. 2019, p. 43). In northern California, a severe decline in bull kelp occurred in conjunction with the marine heatwave of 2014 and 2015, though a number of other ecological factors were involved (Catton et al. 2019, entire). In central California, trends in giant kelp biomass are related to climate cycles such as the NPGO, making the effect of climate change difficult to detect (Bell et al. 2018b, p. 11). It is unclear what the future effects of climate change will be on kelp in the listed range of the marbled murrelet.

In contrast, increases in harmful algal blooms (also known as red tides or toxic algae) have been documented over the past several decades, and these changes are at least partly due to climate change (IPCC 2019, pp. 5-85 – 5-86; Trainer et al. 2003, pp. 216, 222). Future conditions are projected to favor higher growth rates and longer bloom seasons for these species. In the case of one species, *Alexandrium catanella,* increases in the length of bloom season are projected primarily due to increases in sea surface temperature (Moore et al. 2015, pp. 7-9). As with other climate change effects discussed above, increases in the length of the toxic algae bloom season is likely to vary across the listed range. Even within Zone 1, in the eastern end of the Strait of Juan de Fuca and the inlets of southern Puget Sound, the *A. catanella* bloom season is projected to increase by 30 days per year by 2069, in contrast with Whidbey basin, where little or no change in season length is projected (Moore et al. 2015, p. 8). In another genus toxic algae, *Pseudo-nitzschia*, toxin concentrations increase with increasing acidification of the water, especially in conditions in which silicic acid (used to construct the algal cell walls) or phosphate is limiting (Brunson et al. 2018, p. 1; Tatters et al. 2012, pp. 2-3). These and many other harmful alga species also exhibit higher growth rates with higher carbon dioxide concentrations (Brandenburg et al. 2019, p. 4; Tatters et al. 2012, pp. 3-4). During and following the marine heatwave in 2015, an especially large and long-lasting outbreak of *Pseudo-nitzschia* species stretched from southern California to the Aleutian Islands and persisted from May to October, rather than the typical span of a few weeks (Du et al. 2016, pp. 2-3; National Ocean Service 2016; NOAA Climate 2015, p. 1). This harmful algal bloom produced extremely high concentrations of toxic domoic acid, including the highest ever recorded in Monterey Bay, California (NOAA Climate 2015, p. 2; Ryan et al. 2017, p. 5575). With future climate change, toxic algae blooms are likely to be more frequent than in the past, and the larger, more toxic event of 2015 may become more typical (McCabe et al. 2016, p. 10374).

Higher Trophic Levels - There are several pathways by which climate change may affect species at higher trophic levels (i.e, consumers, including marbled murrelets and their prey). Changing physical conditions, such as increasing temperatures, hypoxia, or acidification will have direct effects on some species. Other consumers will be affected via changes in the abundance, distribution, or other characteristics of their competitors or prey species. Changes in the timing of seasonal events may lead to mismatches in the timing of consumers' life history requirements with their habitat conditions (including prey availability as well as physical conditions) (Mackas et al. 2007, p. 249). The combination of these effects is likely to cause changes in community dynamics (e.g. competitive interactions, predator-prey relationships, etc.), but the magnitude of these effects cannot be predicted with confidence (Busch et al. 2013, pp. 827- 831).

A wide variety of marine species are directly affected by ocean acidification. Like their phytoplankton counterparts, foraminiferans and other planktonic consumers that form calcium carbonate shells are less able to form and maintain their shells in acidified waters (Feely et al. 2004, pp. 356-366). Similarly, chemical changes associated with acidification interfere with shell development or maintenance in pteropods (sea snails) and marine bivalves (Busch et al. 2014, pp. 5, 8; Waldbusser et al. 2015, pp. 273-278). These effects on bivalves can be exacerbated by hypoxic conditions (Gobler et al. 2014, p. 5), or ameliorated by very high or low temperatures (Kroeker et al. 2014, pp. 4-5), so it is not clear what the effect is likely to be in a future that includes acidification, hypoxia, and elevated temperatures. Acidification affects crustaceans, for example, slowing growth and development in Pacific krill (*Euphausia pacifica*) and Dungeness crabs (*Cancer magister*) (Cooper et al. 2016, p. 4; Miller et al. 2016, pp. 118-119). Fish, including marbled murrelet prey rockfish species (*Sebastes* spp.) and Pacific herring (*Clupea pallasii*), are also negatively affected by acidification. Depending on species, life stage, and other factors such as warming and hypoxia, these effects include embryo mortality, delayed hatching, reduced growth rates, reduced metabolic rates, altered sensory perception, and changes in behavior, among other effects (Baumann 2019, entire; Hamilton et al. 2014, entire; Nagelkerken and Munday 2016, entire; Ou et al. 2015, pp. 951, 954; Villalobos 2018, p. 18).

Climate effects are expected to alter interactions within the marine food web. When prey items decrease in abundance, their consumers are also expected to decrease, and this can also create opportunities for other species to increase. In California's Farallon Islands, the recently increasing variance of climate drivers is leading to increased variability in abundance of prey species such as euphausiids and juvenile rockfish, associated with corresponding variability in the demography of predators such as seabirds and salmon (Sydeman et al. 2013, pp. 1662, 1667-1672). In future scenarios with strong acidification effects to benthic prey in the California Current, euphausiids and several fish species are expected to decline, while other species are expected to increase (Kaplan et al. 2010, pp. 1973-1976). An investigation of the planktonic food web off of Oregon shows that sea surface temperature has contrasting effects on different types of zooplankton, and competitive interactions are much more prevalent during warm phases of ENSO or PDO than during cool phases (Francis et al. 2012, pp. 2502, 2505-2506). A food web model of Puget Sound shows that moderate or strong acidification effects to calcifying species are expected to result in reductions in fisheries yield for several species, including salmon and Pacific herring, and increased yield for others (Busch et al. 2013, pp. 827-829). Additionally, the same model shows that these ocean acidification effects are expected to cause reductions in forage fish biomass, which are in turn expected to lead to reductions in diving bird biomass (Busch et al. 2013, p. 829). While Busch and coauthors (2013, p. 831) express confidence that this model is accurate in terms of the nature of ocean acidification effects to the Puget Sound food web of the future, they are careful to note that there is a great deal of uncertainty when it comes to the magnitude of the changes. The model also illustrates that some of the effects to the food web will dampen or make up for other effects to the food web, so that changes in abundance of a given prey species will not always correspond directly to changes in the abundance of their consumers (Busch et al. 2013, pp. 827, 830).

Changes in seasonality at lower trophic levels may lead to changes in population dynamics or in interactions between species at higher trophic levels. In central and northern California, reproductive timing and success of common murres (*Uria aalge*) and Cassin's auklets (*Ptychoramphus aleuticus*) are related to not only the strength but also the seasonal timing of upwelling, as are growth rates of *Sebastes* species (Black et al. 2011, p. 2540; Holt and Mantua 2009, pp. 296-297; Schroeder et al. 2009, p. 271). At the northern end of the California Current, Triangle Island in British Columbia, Cassin's auklet breeding success is reduced during years when the peak in copepod prey availability comes earlier than the birds' hatch date, and this mismatch is associated with warm sea surface temperatures (Bertram et al. 2009, pp. 206-207; Hipfner 2008, pp. 298-302). However, piscivorous seabirds (tufted puffins [*Fratercula cirrhata*], rhinoceros auklets [*Cerorhinca monocerata*], and common murres) breeding at the same Triangle Island site have, at least to some extent, been able to adjust their breeding dates according to ocean conditions (Bertram et al. 2001, pp. 292-293; Gjerdrum et al. 2003, p. 9379), as have Cassin's auklets breeding in the Farallon Islands of California (Abraham and Sydeman 2004, p. 240). Because of the changes in tufted puffin, rhinoceros auklet, and common murre hatch dates at Triangle Island, the breeding periods of these species have converged to substantially overlap with one another and with that of Cassin's auklet (Bertram et al. 2001, pp. 293-294), but studies have not addressed whether this overlap has consequences for competitive interactions among the four species. Note that all four of these bird species are in the family Alcidae, which also contains marbled murrelets. All these species also breed and forage within the listed range of the marbled murrelet.

Several studies have suggested that climate change is one of several factors allowing jellyfish to increase their ecological dominance, at the expense of forage fish (Parsons and Lalli 2002, pp. 117-118; Purcell et al. 2007, pp. 154, 163, 167-168; Richardson et al. 2009, pp. 314-216). Many (though not all) species of jellyfish increase in abundance and reproductive rate in response to ocean warming, and jellyfish are also more tolerant of hypoxic conditions than fish are (Purcell 2005, p. 472; Purcell et al. 2007, pp. 160, 163; see Suchman et al. 2012, pp. 119-120 for a Northeastern Pacific counterexample). Jellyfish may also be more tolerant of acidification than fish are (Atrill et al. 2007, p. 483; Lesniowski et al. 2015, p. 1380). In the California Current, jellyfish populations appear to be increasing, but nearshore areas are likely to be susceptible to being dominated by jellyfish, rather than forage fish (Schnedler-Meyer et al. 2016, p. 4). Jellyfish abundance in southern and central Puget Sound has increased since the 1970s (Greene et al. 2015, p. 164). Over the same time period, herring abundance has decreased in south and central Puget Sound, and surf smelt (*Hypomesus pretiosus*) abundance has also decreased in south Puget Sound, although other Puget Sound forage fish populations have been stable or increasing (Greene et al. 2015, pp. 160-162). Forage fish abundance and jellyfish abundance were negatively correlated within Puget Sound and Rosario Strait (Greene et al. 2015, p. 164). In the northern California Current, large jellyfish and forage fish have similar diet composition and likely compete for prey, in addition to the two groups' contrasting responses to climate and other anthropogenic factors (Brodeur et al. 2008, p. 654; Brodeur et al. 2014, pp. 177-179).

Many species of forage fish are expected to fare poorly in the changing climate, regardless of any competitive effects of jellyfish. North of the listed range, in the Gulf of Alaska, Anderson and Piatt (1999, pp. 119-120) documented the crash of capelin (*Mallotus villosus*), Pacific herring, and species of Irish lord (*Hemilepidotus* spp.), prickleback (Stichaeidae family), greenlings and mackerel (*Hexagrammos* and *Pleurogrammus* spp.), as well as several shrimp species, as part of a major community reorganization following a climate regime shift from a cool phase to a warm phase in the 1970s. In the northeastern Pacific Ocean, capelin, sand lance (Ammodytidae family), and rockfish abundance are all negatively correlated with seasonal sea surface temperatures (Thayer et al. 2008, p. 1616). A model of multiple climate change effects (e.g., acidification and deoxygenation) to marine food webs in the Northeast Pacific consistently projects future declines in small pelagic fish abundance (Ainsworth et al. 2011, pp. 1219, 1224). Within Zone 1, abundance of surf smelt and Pacific herring in the Skagit River estuary are positively associated with coastal upwelling during the spring and early summer, likely because nutrient-rich upwelled water increases food availability (Reum et al. 2011, pp. 210-212). If projections of later, shorter upwelling seasons are correct (see above), the delays may lead to declines in these stocks of herring and surf smelt, as happened in 2005 (Reum et al. 2011, p. 212). Similarly, delayed upwelling in 2005 led to reduced growth rates, increased mortality, and recruitment failure of juvenile northern anchovies off of the Oregon and Washington coasts (Takahashi et al. 2012, pp. 397-403). In contrast, anchovy abundance in Zone 1 was unusually high in 2005, as it was in 2015 and 2016 following the marine heatwave, and is positively associated with sea surface temperature (Duguid et al. 2019, p. 38). In the northeastern Pacific, Chavez and coauthors (2003, pp. 217-220) have described a shift between an "anchovy regime" during the cool negative phase of the PDO and a "sardine regime" during the warm positive phase, where the two regimes are associated with contrasting physical and biological states. However, global warming may disrupt the ecological response to the naturally-occurring oscillation, or alter the pattern of the oscillation itself (Chavez et al. 2003, p. 221; Zhang and Delworth 2016, entire).

Marbled murrelets - Marbled murrelets are likely to experience changes in foraging and breeding ecology as the climate continues to change. Although studies are not available that directly project the effects of marine climate change on marbled murrelets, several studies have been conducted within and outside the listed range regarding ocean conditions and marbled murrelet behavior and fitness. Additionally, numerous studies of other alcids from Mexico to British Columbia indicate that alcids as a group are vulnerable to climate change in the northeastern Pacific.

These studies suggest that the effects of climate change will be to reduce marbled murrelet reproductive success, and to some extent, survival, largely mediated through climate change effects to prey. In British Columbia, there is a strong negative correlation between sea surface temperature and the number of marbled murrelets observed at inland sites displaying behaviors associated with nesting (Burger 2000, p. 728). In central California, marbled murrelet diets vary depending on ocean conditions, and there is a trend toward greater reproductive success during cool water years, likely due to the abundant availability of prey items such as euphausiids and juvenile rockfish (Becker et al. 2007, pp. 273-274). Across the northern border of the listed range, in the Georgia Basin, much of the yearly variation in marbled murrelet abundance from 1958 through 2000 can be explained by the proportion of fish (as opposed to euphausiids or amphipods) in the birds' diet (Norris et al. 2007, p. 879). If climate change leads to further declines in forage fish populations (see above), those declines are likely to be reflected in marbled murrelet populations.

The conclusion that climate change is likely to reduce marbled murrelet breeding success via changes in prey availability is further supported by several studies of other alcid species in British Columbia and California. Common murres, Cassin's auklets, rhinoceros auklets, and tufted puffins in British Columbia; common murres in Oregon; pigeon guillemots (*Cepphus columba*), common murres, and Cassin's auklets in California; and even Cassin's auklets in Mexico all show altered reproductive rates, altered chick growth rates, or changes in the timing of the breeding season, depending on sea surface temperature or other climatic variables, prey abundance, prey type, or the timing of peaks in prey availability (Abraham and Sydeman 2004, pp. 239-243; Ainley et al. 1995, pp. 73-77; Albores-Barajas 2007, pp. 85-96; Bertram et al. 2001, pp. 292-301; Borstad et al. 2011, pp. 291-299; Gjerdrum et al. 2003, pp. 9378-9380; Hedd et al. 2006, pp. 266-275; Piatt et al. 2020, pp. 13-15; Sydeman et al. 2006, pp. 2-4). The abundance of Cassin's auklets and rhinoceros auklets off southern California declined by 75 and 94 percent, respectively, over a period of ocean warming between 1987 and 1998 (Hyrenbach and Veit 2003, pp. 2546, 2551). Although the details of the relationships between climate variables, prey, and demography vary between bird species and locations, the consistent demonstration of such relationships indicates that alcids as a group are sensitive to climate-related changes in prey availability, prompting some researchers to consider them indicator species for climate change (Hedd et al. 2006, p. 275; Hyrenbach and Veit 2003, p. 2551).

In addition to effects on foraging ecology and breeding success, climate change may expose adult and juvenile marbled murrelets to health risks. These risks include poisoning, and potentially feather fouling, from harmful algal blooms, as well as from anthropogenic toxins. Climate change can also cause unexpected changes in disease exposure. Reductions in forage fish quality and availability may also lead to starvation in extreme circumstances, though in less extreme circumstances these reductions are more likely to preclude breeding, which could, counterintuitively, increase adult survival.

It is likely that marbled murrelets will experience more frequent domoic acid poisoning, as this toxin originates from harmful algae blooms in the genus *Pseudo-nitzchia*, which are expected to become more prevalent in the listed range (see above). In central California, domoic acid poisoning was determined to be the cause of death for at least two marbled murrelets recovered during a harmful algae bloom in 1998 (Peery et al. 2006, p. 84). During this study, which took place between 1997 and 2003, the mortality rate of radio-tagged marbled murrelets was highest during the algae bloom (Peery et al. 2006, p. 83). Domoic acid poisoning has previously been shown to travel through the food chain to seabirds via forage fish that feed on the toxic algae (Work et al. 1993, p. 59). Other types of harmful algae, including the *Alexandrium* genus, which is also likely to become more prevalent in the listed range (see above), produce saxitoxin, a neurotoxin that causes paralytic shellfish poisoning. Consumption of sand lance contaminated with saxitoxin was implicated in the deaths of seven out of eight (87.5 percent) of Kittlitz's marbled murrelet (*Brachyramphus brevirostrus*) chicks that were tested following nest failure at a study site in Alaska in 2011 and 2012 (Lawonn et al. 2018, pp. 11-12; Shearn-Bochsker et al. 2014). Yet another species of harmful algae produces a foam that led to plumage fouling and subsequent mortality of common murres and other seabird species off of Oregon and Washington during October of 2009, and similar events may become more frequent with climate change (Phillips et al. 2011, pp. 120, 122-124). Due to changes in the Salish Sea food web, climate change is projected to increase mercury and, to a lesser extent, polychlorinated biphenyls (PCB) levels in forage fish and top marine predators (Alava et al. 2018, pp. 4); presumably marbled murrelets will experience a similar increase.

Climate change may also promote conditions in which alcids become exposed to novel pathogens, as occurred in Alaska during 2013, when crested auklets (*Aethia cristatella*) and thick-billed murres (*Uria lomvia*) washed ashore after dying of avian cholera (Bodenstein et al. 2015, p. 935). Marbled murrelets in Oregon may be especially susceptible to novel diseases, because these populations lack diversity in genes related to immunity (Vásquez-Carrillo et al. 2014, p. 252).

In extreme warm-water conditions, adult marbled murrelets may suffer starvation, as occurred with common murres during the marine heatwave of 2014-2016. High levels of adult mortality were observed among common murres from California to Alaska, and this mortality was likely caused by a combination of reductions in forage fish nutritional content and increases in competition with large piscivorous fish, a combination termed the "ectothermic vise" (Piatt et al. 2020, pp. 17-24). Counterintuitively, in the 1997-2003 study of radio tagged marbled murrelets in California, marbled murrelet adult survival was higher during warm-water years and lower during cold-water years, likely because they did not breed and therefore avoided the associated physiological stresses and additional predator risk (Peery et al. 2006, pp. 83-85).

Overall, the effects of climate change in marine ecosystems are likely to be complex, and will vary across the range. Alterations in the physical properties of the marine environment will affect the productivity and composition of food webs, which are likely to affect the abundance, quality, and availability of food resources for marbled murrelets. These changes, in turn, will affect marbled murrelet reproductive performance. In addition, toxic algae and potentially disease organisms are expected to present increasing risks to marbled murrelet health and survival. Different types of effects can be predicted with varying levels of certainty. For example, large increases in the prevalence of harmful algal blooms have already been observed, whereas the likely future magnitude and direction of overall changes in net primary productivity remain highly uncertain. Some changes may be positive (for example, the potential for a northward shift in anchovy abundance), but on the whole climate change is expected to have a detrimental effect to marbled murrelet foraging and health.

Summary of Climate Change Effects

In summary, marbled murrelets are expected to experience effects of climate change in both their nesting habitat and marine foraging habitat. Natural disturbances of nesting habitat are expected to become more frequent, leading to accelerated habitat losses that may outpace ingrowth even in protected landscapes. Marine food chains are likely to be altered, and the result may be a reduction in food resources for marbled murrelets. Even if food resources remain available, the timing and location of their availability may shift, which may alter marbled murrelet nesting seasons or locations. In addition, health risks from harmful algal blooms, anthropogenic toxins, and perhaps pathogens are likely to increase with climate change.

Within the marine environment, effects on the marbled murrelet food supply (amount, distribution, quality) provide the most likely mechanism for climate change impacts to marbled murrelets. Studies in British Columbia (Norris et al. 2007) and California (Becker and

Beissinger 2006) have documented long-term declines in the quality of marbled murrelet prey, and one of these studies (Becker and Beissinger 2006, p. 475) linked variation in coastal water temperatures, marbled murrelet prey quality during pre-breeding, and marbled murrelet reproductive success. These studies indicate that marbled murrelet recovery may be affected as long-term trends in ocean climate conditions affect prey resources and marbled murrelet reproductive rates. While seabirds such as the marbled murrelet have life-history strategies adapted to variable marine environments, ongoing and future climate change could present changes of a rapidity and scope outside the adaptive range of marbled murrelets (USFWS 2009, p. 46).

Conservation Needs of the Species

Reestablishing an abundant supply of high-quality marbled murrelet nesting habitat is a vital conservation need given the extensive removal during the 20th century. Even following the establishment of the NWFP, habitat continued to be lost between 1993 and 2012, and the rate of loss on non-federal lands has been 10 times greater than on federal lands (Raphael et al. 2016b, pp. 80-81). If this rate of loss continues, the conservation of the marbled murrelet may not be possible because almost half of the higher-suitability nesting habitat is on non-federal lands (Raphael et al. 2016b, p. 86). Therefore, recovery of the marbled murrelet will be aided if areas of currently suitable nesting habitat on non-federal lands are retained until ingrowth of habitat on federal lands provides replacement nesting opportunities (USFWS 2019, p. 21).

There are also other conservation imperatives. Foremost among the conservation needs are those in the marine and terrestrial environments to increase marbled murrelet fecundity by increasing the number of breeding adults, improving marbled murrelet nest success (increasing nestling survival and fledging rates), and reducing anthropogenic stressors that reduce individual fitness or lead to mortality. The overall reproductive success (fecundity) of marbled murrelets is directly influenced by nest predation rates (reducing nestling survival rates) in the terrestrial environment and an abundant supply of high quality prey in the marine environment before and during the breeding season (improving breeding rates, potential nestling survival, and fledging rates). Anthropogenic stressors affecting marbled murrelet fitness and survival in the marine environment are associated with commercial and tribal gillnets, derelict fishing gear, oil spills, and high underwater sound pressure (energy) levels generated by pile-driving and underwater detonations (which can be lethal or reduce individual fitness). Anthropogenic activities, such as coastline modification and nutrient inputs in runoff, also affect prey availability and harmful algal blooms, which in turn affect marbled murrelet fitness.

Further research regarding marine threats, general life history, and marbled murrelet population trends in the coastal redwood zone may illuminate additional conservation needs that are currently unknown (USFWS 2019, p. 66).

Recovery Plan

The Marbled murrelet Recovery Plan outlines the conservation strategy with both short- and long-term objectives. The Plan places special emphasis on the terrestrial environment for habitat-based recovery actions due to nesting occurring in inland forests.

In the short-term, specific actions identified as necessary to stabilize the populations include protecting occupied habitat and minimizing the loss of unoccupied but suitable habitat (USFWS 1997, p. 119). Specific actions include maintaining large blocks of suitable habitat, maintaining and enhancing buffer habitat, decreasing risks of nesting habitat loss due to fire and windthrow, reducing predation, and minimizing disturbance. The designation of critical habitat also contributes towards the initial objective of stabilizing the population size through the maintenance and protection of occupied habitat and minimizing the loss of unoccupied but suitable habitat.

Long-term conservation needs identified in the Plan include:

- Increasing productivity (abundance, the ratio of juveniles to adults, and nest success) and population size.
- Increasing the amount (stand size and number of stands), quality, and distribution of suitable nesting habitat.
- Protecting and improving the quality of the marine environment.
- Reducing or eliminating threats to survivorship by reducing predation in the terrestrial environment and anthropogenic sources of mortality at sea.

General criteria for marbled murrelet recovery (delisting) were established at the inception of the Plan and they have not been met (USFWS 2019, p. 65). More specific delisting criteria are expected in the future to address population, demographic, and habitat based recovery criteria (USFWS 1997, p. 114-115). The general criteria include:

- Documenting stable or increasing population trends in population size, density, and productivity in four of the six Conservation Zones for a 10-year period.
- Implementing management and monitoring strategies in the marine and terrestrial environments to ensure protection of marbled murrelets for at least 50 years.

Thus, increasing marbled murrelet reproductive success and reducing the frequency, magnitude, or duration of any anthropogenic stressor that directly or indirectly affects marbled murrelet fitness or survival in the marine and terrestrial environments are the priority conservation needs of the species. The Service estimates recovery of the marbled murrelet will require at least 50 years (USFWS 1997).

<u>Survival and Recovery Role of Each Conservation Zone</u>

The six Conservation Zones, defined in the Recovery Plan as equivalent to Recovery Units, vary not only in their population status, as described above, but also in their intended function with respect to the long-term survival and recovery of the marbled murrelet.

Conservation Zones 1 extends inland 50 miles from the marine waters of Puget Sound and most waters of the Strait of Juan de Fuca south of the U.S.-Canadian border. The terrestrial portion of Zone 1 includes the north Cascade Mountains and the northern and eastern sections of the Olympic Peninsula. Nesting habitat in the Cascades is largely separated from high-quality marine foraging habitat by both urban development on land and highly altered coastal marine environments, leading to long commutes between nesting and foraging habitat (Lorenz et al. 2017, p. 314; Raphael et al. 2016a, p. 106; USFWS 1997, p. 125). In contrast, large blocks of nesting habitat remain near the coast along the Strait of Juan de Fuca, where there is a lower human footprint (Raphael et al. 2016b, p. 72; van Dorp and Merrick 2017, p. 5). This combination of large blocks of habitat close to foraging habitat is likely more conducive to successful production of young than conditions other portions of Zone 1. Zone 1 is unique among the six Zones in that the marine environment is not a part of the California Current ecosystem, but is part of a complex system of estuaries, fjords, and straits. This means that the Zone 1 population is subject to a different set of environmental influences than the populations in the other five zones. For example, in 2005, delayed upwelling led to widespread nesting failure of seabirds, including marbled murrelets, along the northern California Current, while above-average productivity was observed in Zone 1 (Lorenz and Raphael 2018, pp. 208-209; Peterson et al. 2006, pp. 64, 71; Ronconi and Burger 2008, p. 252; Sydeman et al. 2006, p. 3). This example illustrates the importance of Zone 1 in bolstering the rangewide resilience of marbled murrelets. Zone 1 is one of the four Zones where increased productivity and stable or increasing population size are needed to provide redundancy and resilience that will enable recovery and long-term survival.

Conservation Zone 2 also extends inland 50 miles from marine waters. Conservation Zone 2 includes marine waters within 1.2 miles (2 km) off the Pacific Ocean shoreline, with the northern terminus immediately south of the U.S.-Canadian border near Cape Flattery along the midpoint of the Olympic Peninsula, and extending to the southern border of Washington (the Columbia River) (USFWS 1997, pg. 126). Although Zone 2 was defined to include only the nearshore waters, marbled murrelets in this area are regularly found up to 8 km from shore, sometimes at higher densities than in the nearshore environment, even during the breeding season (Bentivoglio et al. 2002, p. 29; McIver et al. in press, pp. 34, 85). Zone 2 includes the rich waters of the Olympic Coast National Marine Sanctuary, which are adjacent to areas of the Olympic Peninsula that retain large blocks of nesting habitat (Raphael et al. 2016b, p. 72). Like the northern Olympic Peninsula in Zone 1, parts of the western Olympic Peninsula appear to provide one of the few remaining strongholds for marbled murrelets in Washington. The southern portion of Zone 2 previously hosted a small but consistent subpopulation of nesting marbled murrelets, and is now only sparsely used for nesting inland or foraging at sea. This reduction in marbled murrelet population density in the southern portion of Zone 2 represents a widening of a gap in distribution that was described in the Recovery Plan (USFWS 1997, p. 126). This gap is likely a partial barrier to gene flow (USFWS 1997, p. 145). The eventual long-term survival and recovery of listed marbled murrelets depends on the maintenance of a viable marbled murrelet populations that are well distributed throughout Zone 2, along with the other three Zones where increased productivity and stable or increasing population size are needed for survival and recovery.

Conservation Zone 3 extends 35 miles inland, and includes marine waters within 1.2 miles of the Pacific Ocean shoreline between the northern border of Oregon (the Columbia River) and North Bend, Oregon (USFWS 1997, pp. 126-127). The terrestrial portion of Zone 3 historically experienced large-scale wildfires and timber harvest, which together likely led to a loss of nesting habitat that caused a dramatic decline in the marbled murrelet population in this Zone (USFWS 1997, p. 117). In the northern portion of Zone 3, this lack of nesting habitat persists, and the at-sea population density of marbled murrelets is relatively low, extending the gap in the southern portion Zone 2 (USFWS 1997, p. 145; McIver et al. 2021, pp. 11-17). Additionally, marbled murrelet populations in Oregon are expected to be more susceptible to novel pathogens, due to low genetic diversity coding for important immune system peptides (Vásquez-Carrillo et al. 2014, p. 252). However, in Zone 3 as a whole, at-sea population density is high, and is trending upward, though the reason for the population increase is not well understood. The marbled murrelet population of Zone 3 is one of the two largest among the Conservation Zones. The eventual long-term survival and recovery of listed marbled murrelets depends on the maintenance of a viable marbled murrelet populations that is well distributed throughout Zone 3, along with the other three Zones where increased productivity and stable or increasing population size are needed for survival and recovery.

Conservation Zone 4 extends 35 miles inland, and includes marine waters within 1.2 miles of the Pacific Ocean shoreline between North Bend, Oregon and the southern end of Humboldt County, California (USFWS 1997, p. 127). Since 1993, this Zone has experienced the majority of all nesting habitat losses on federal lands within the listed range, nearly all due to large wildfires (Raphael et al. 2016b, p. 75). Much of the nesting habitat within this Zone is located within National and California State Parks, and recreation likely reduces marbled murrelet productivity in these areas, particularly via accidental food subsidies to corvid nest predators at picnic sites and camping areas (USFWS 1997, p. 128). Over the last decade, Redwood National and State Parks have made efforts to reduce this supplemental feeding of corvids, with some success in reducing corvid density at recreation sites, but it would be difficult to detect any population-scale benefit of these efforts (Brunk et al. 2021, pp. 7-8; McIver et al., in press, p. 43). The marbled murrelet population of Zone 4 is one of the two largest among the Conservation Zones, and is increasing, though the reason for the population increase is not well understood. The eventual long-term survival and recovery of listed marbled murrelets depends on the maintenance of a viable marbled murrelet populations that is well distributed throughout Zone 4, along with the other three Zones where increased productivity and stable or increasing population size are needed for survival and recovery.

Conservation Zone 5 extends 25 miles inland, and includes marine waters within 1.2 miles of the Pacific Ocean shoreline between the southern end of Humboldt County, California, and the mouth of San Francisco Bay (USFWS 1997, p. 129). Very little nesting habitat remains in this Zone, mostly in California State Parks and on private lands, though some nesting habitat ingrowth was observed between 1993 and 2012 (Raphael et al. 2016b, p. 75; USFWS 1997, p. 129). Marbled murrelet population estimates in Zone 5 have been correspondingly low, with population estimates of less than 100 individuals in most survey years (McIver et al. 2021, pp. 11-17). The most recent survey, in 2017, resulted in a much higher estimate of 872 individuals, but multiple lines of evidence indicate that this increase was likely the result of unusual migratory patterns from other Zones during the breeding season (Adrean et al. 2018, p. 2; McIver et al., in press, pp. 43-44; Strong 2018, pp. 6-7). However, surveys in Zone 5 are now conducted only once every four years, making the status and trend of this population more difficult to discern. Given the small size of the population during most survey years, and the limited availability of nesting habitat, the ability of this population to survive over the coming decades is questionable, and Zone 5 cannot be counted on to contribute toward long-term survival or recovery of the DPS (USFWS 1997, pp. 129). In the best-case scenario, if nesting habitat ingrowth in this Zone can stimulate the restoration of a larger population in Zone 5 over the long term, this would likely improve connectivity between Zones 4 and 6, provide redundancy, and increase resiliency for the DPS as a whole.

Conservation Zone 6 extends 15 miles inland, and includes marine waters within 1.2 miles of the Pacific Ocean shoreline between the mouth of San Francisco Bay and Point Sur, in Monterey County, California (USFWS 1997, pp. 129-130). Zone 6 is unique among the Zones in that it is not within the NWFP area and is not included in NWFP effectiveness monitoring. Federal land is lacking in Zone 6, and all nesting habitat is located within State or County Parks or on private lands (McShane et al. 2004, p. 4-14). Marbled murrelet population estimates for Zone 6 have averaged around 500 individuals for the period from 1999 through 2019, with a range between 174 and 699 birds across the years (Felis et al. 2020, p. 7). The Zone 6 population is genetically differentiated from the other Zones, likely as a result of the wide gap in the range between the Zone 6 population and the populations to the north (Hall et al. 2009, p. 5078; Peery et al. 2010, p. 703). When the Recovery Plan was written in 1997, it was anticipated that the Zone 6 population would persist long enough to contribute to recovery, but could not be relied upon to contribute to the long-term survival of the species (USFWS 1997, p. 116). Subsequent research has demonstrated that the population in Zone 6 is a demographic sink, with a shrinking breeding population bolstered by the presence of mainly non-breeding individuals originating from other Zones (Peery et al. 2006, p. 1523; Peery et al. 2010, p. 702; Vásquez-Carrillo et al. 2013, p. 177). Demographic effects of large-scale nesting habitat loss and degradation during the 2020 wildfires have not yet manifested, but are expected to be negative. Therefore, it remains unlikely that this population will contribute to recovery. The presence of a marbled murrelet population in Zone 6 is necessary to ensure the future distribution of marbled murrelets throughout their current and historical within the DPS, but it is not clear that this will be possible over the long term, given the vulnerability of this population to stochastic or catastrophic events (USFWS 1997, p. 116). The Recovery Plan identified lands that will be essential for the recovery of the marbled murrelet, including1) any suitable habitat in a Late Successional Reserve (LSR) in Forest Ecosystem Management Assessment Team (FEMAT) Zone 1 (not to be confused with Conservation Zone 1), as well as LSR in FEMAT Zone 2 in Washington, 2) all suitable habitat located in the Olympic Adaptive Management Area, 3) large areas of suitable nesting habitat outside of LSRs on Federal lands, such as habitat located in the Olympic National Park, 4) suitable habitat on State lands within 40 miles of the coast in Washington, or within 25 miles of the coast in Oregon and California, 5) habitat within 25 miles of the coast on county park land in San Mateo and Santa Cruz Counties, California, 6) suitable nesting habitat on Humboldt Redwood Company (formerly Pacific Lumber Company) lands in Humboldt County, California, and 5) habitat within occupied marbled murrelet sites on private lands (USFWS 1997, pp. 131-133).

Marine habitat is also essential for the recovery of the marbled murrelet. Key recovery needs in the marine environment include protecting the quality of the marine environment and reducing adult and juvenile mortality at sea (USFWS 1997, pp. 134-136). Marine areas identified as essential for marbled murrelet foraging and loafing include 1) all waters of Puget Sound and the Strait of Juan de Fuca, and waters within 1.2 miles of shore 2) along the Pacific Coast from Cape Flattery to Willapa Bay in Washington, 3) along the Pacific Coast from Newport Bay to Coos Bay in Oregon, 4) along the Pacific Coast from the Oregon-California border south to Cape Mendocino in northern California, and 5) along the Pacific Coast in central California from San Pedro Point south to the mouth of the Pajaro River.

Summary

At the range-wide scale, annual estimates of marbled murrelet populations have fluctuated, with no conclusive evidence of a positive or negative trend since 2001(+0.5 percent per year, 95% CI: -0.5 to +1.5%) (McIver et al. 2021, p. 4). The most recent extrapolated population estimate for the entire NWFP area was 21,200 marbled murrelets (95 percent CI: 16,400 to 26,000 birds) in

2019 (McIver et al. 2021, p. 3). The largest and most stable marbled murrelet subpopulations now occur off the Oregon and northern California coasts, while subpopulations in Washington have steadily declined since 2001 (-3.9 percent per year; 95% CI: -5.4 to -2.4%) (McIver et al. 2021, p. 4).

Monitoring of marbled murrelet nesting habitat within the NWFP area indicates nesting habitat declined from an estimated 2.53 million acres in 1993 to an estimated 2.23 million acres in 2012, a decline of about 12.1 percent (Raphael et al. 2016b, p. 72). Marbled murrelet population size is strongly and positively correlated with amount of nesting habitat, suggesting that conservation of remaining nesting habitat and restoration of currently unsuitable habitat is key to marbled murrelet recovery (Raphael et al. 2011, p. iii). Given likely future increases in forest disturbances that can cause habitat loss, conservation of remaining nesting habitat is especially important.

The species decline has been largely caused by extensive removal of late-successional and old growth coastal forest which serves as nesting habitat for marbled murrelets. Additional factors in its decline include high nest-site predation rates and human-induced mortality in the marine environment from disturbance, gillnets, and oil spills. In addition, marbled murrelet reproductive success is strongly correlated with the abundance of marine prey species. Overfishing and oceanographic variation from climate events and long-term climate change have likely altered both the quality and quantity of marbled murrelet prey species (USFWS 2009, p. 67).

Although some threats have been reduced (e.g., habitat loss on Federal lands), some threats continue, and new threats now strain the ability of the marbled murrelet to successfully reproduce. Threats continue to contribute to marbled murrelet population declines through adult and juvenile mortality and reduced reproduction. Therefore, given the current status of the species and background risks facing the species, it is reasonable to assume that marbled murrelet populations in Conservation Zones 1 and 2 and throughout the listed range have low resilience to deleterious population-level effects and are at high risk of continuing or renewed declines. Activities that degrade the existing conditions of occupied nesting habitat or reduce adult survivorship or nest success of marbled murrelets will be of greatest consequence to the species. Actions resulting in the loss of occupied nesting habitat, mortality to breeding adults, eggs, or nestlings will reduce productivity, contribute to continued population declines, and prolong population recovery within the listed range of the species in the coterminous United States.

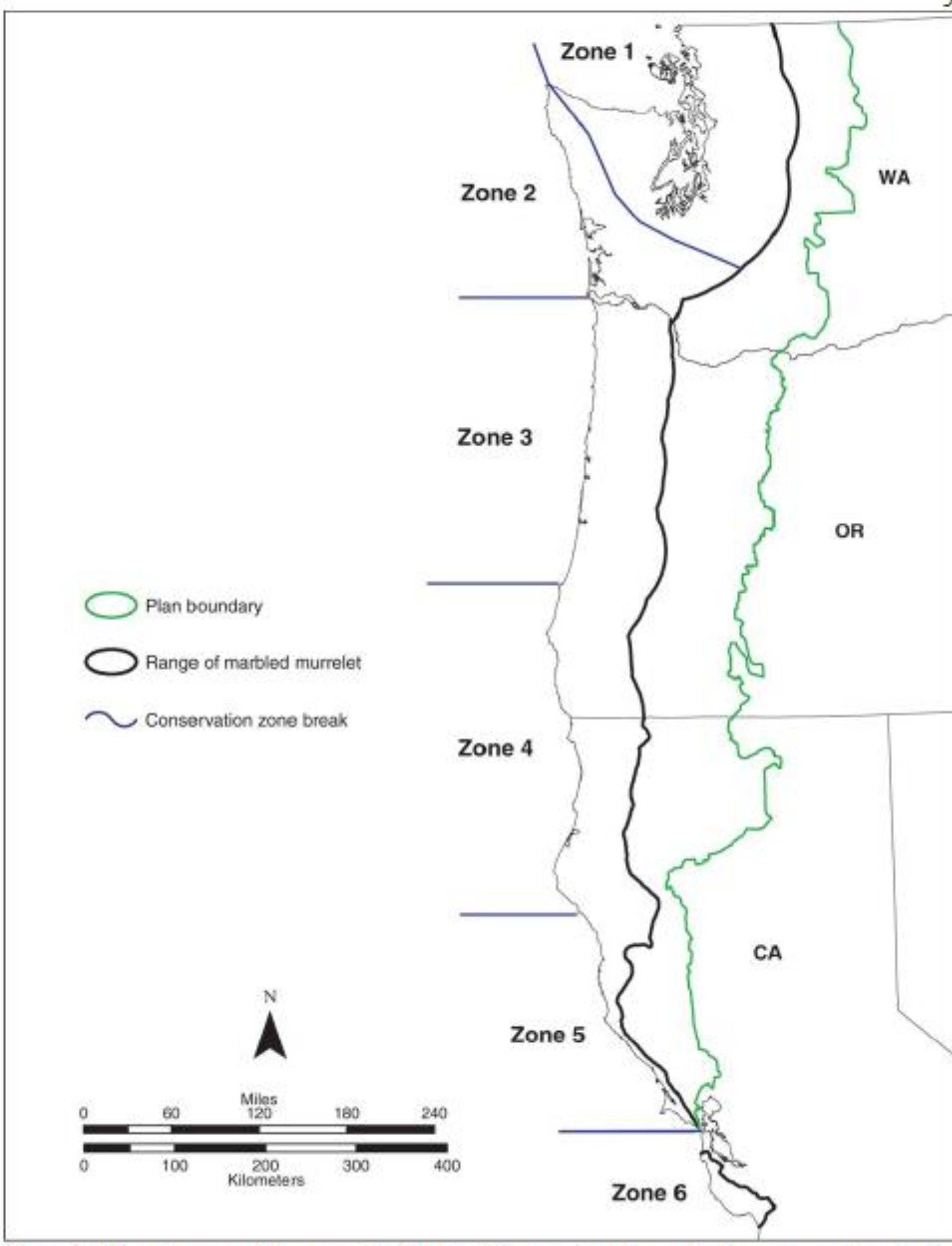

Figure 3. The six geographic areas identified as Conservation Zones in the recovery plan for the marbled murrelet (USFWS 1997). Note: "Plan boundary" refers to the NWFP. Figure adapted from Huff et al. (2006, p. 6).

Environmental Baseline

Environmental baseline refers to the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline.

Marbled Murrelet Status in the Action Area

The action area includes portions of the current range of the marbled murrelet in nearshore marine and open water marine habitats in Washington and Oregon. The action area includes the marine portions of four marbled murrelet Recovery Units (or "Conservation Zones"): Conservation Zone 1 – Puget Sound, Conservation Zone 2 – Western Washington Coast Range, Conservation Zone 3 – Oregon Coast Range, and Conservation Zone 4 – Siskiyou Coast Range (Figure 4).

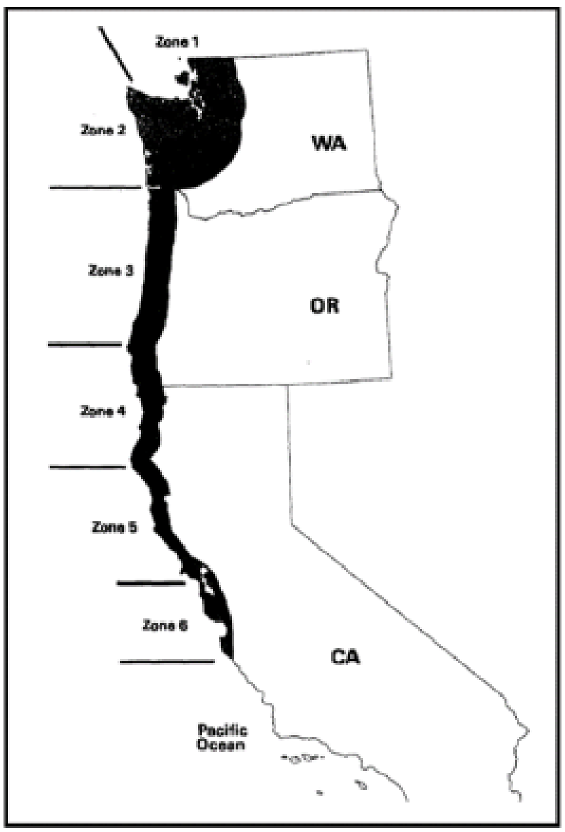

Figure 4. Marbled murrelet Conservation Zones (USFWS 1997, pg. 114).

Conservation Zone 1 (Puget Sound) includes all the waters of Puget Sound and most waters of the Strait of Juan de Fuca south of the U.S.-Canadian border. Within the Inland Water Subunit, marbled murrelets tend to forage in well-defined areas during the breeding season. They are found in the highest densities in the nearshore waters of the San Juan Islands, Rosario Strait, the Strait of Juan de Fuca, Admiralty Inlet, and Hood Canal. They are more sparsely distributed elsewhere in Puget Sound, with smaller numbers observed within the Nisqually Reach, Possession Sound, Skagit Bay, Bellingham Bay, and along the eastern shores of Georgia Strait. In the most southern end of Puget Sound, they occur in extremely low numbers. During the non-breeding season, marbled murrelets typically disperse and are found farther from shore (Strachan et al. 1995, pp. 247-253). Marbled murrelets from Vancouver Island, British Columbia may move into more sheltered waters in Puget Sound and the Strait of Georgia during the non-breeding season, which may contribute to increased numbers of marbled murrelets in Puget Sound in fall and winter (Beauchamp et al. 1999, entire; Burger 1995, pg. 297; Ralph et al. 1995, pg. 9; Speich and Wahl 1995, pg. 325).

Conservation Zone 2 (Western Washington Coast Range) includes marine waters within 1.2 miles (2 km) of the Pacific Ocean shoreline, with the northern terminus immediately south of the U.S.-Canadian border near Cape Flattery along the midpoint of the Olympic Peninsula, and extending to the southern border of Washington (the Columbia River) (USFWS 1997, pg. 126). During the breeding season (April through September), marbled murrelet density in the Offshore Area Subunit is lower than in the nearshore coastal and inland waters. During the summer, it is assumed that 5 percent of marbled murrelets detected by the Northwest Forest Plan Effectiveness Monitoring Program are offshore (the survey effort detects approximately 95 percent of the population, and the remaining 5 percent are assumed to be offshore), but not beyond the continental shelf (37 km, or 20 nm).

Conservation Zone 3 (Oregon Coast Range) extends from the Columbia River south to North Bend, Coos County, Oregon, includes waters within 1.2 miles (2 km) of the Pacific Ocean shoreline, and extends inland a distance of approximately 35 miles (56 km). The boundary encompasses all of the designated marbled murrelet CHUs (USFWS 1997, pp. 126, 127).

Conservation Zone 4 (Siskiyou Coast Range) extends from North Bend, Coos County, Oregon, south to the southern end of Humboldt County, California. It includes waters within 1.2 miles (2 km) of the Pacific Ocean shoreline (including Humboldt and Arcata bays) and, in general, extends inland a distance of 35 miles (56 km) (USFWS 1997, pg. 127).

Current Conditions and Limiting Factors in the Action Area

Current conditions and limiting factors in the action area are the same as those described rangewide below.

- The loss of nesting habitat was a major cause of decline over the past century and may still be contributing as nesting habitat continues to be lost to fires, logging, and windstorms (Miller et al. 2012, pg. 778). Due mostly to historic timber harvest, only a small percentage (approximately 11 percent) of the habitat-capable lands within the listed range contain potential nesting habitat (Raphael et al. 2016b, pg. 69).

- While the direct causes for population declines are unknown, potential factors include the loss of nesting habitat, including cumulative and time-lag effects of habitat losses over the past 20 years, changes in the marine environment reducing the availability or quality of prey, increased densities of nest predators, and emigration (Miller et al. 2012, pg. 778). Marine habitat degradation is most prevalent in the Puget Sound, where human activities (e.g., shipping lanes, boat traffic, shoreline development) are an important factor influencing the marine distribution and abundance in Conservation Zone 1 (Falxa and Raphael 2016, pg. 110).

- Populations are declining in Washington, stable in Oregon, and stable in California where there is a non-significant but positive population trend (McIver et al. 2019, pg. 3). Population size and distribution is strongly and positively correlated with the amount and pattern of suitable nesting habitat (i.e., large contiguous patches); population trend is most strongly correlated with trend in nesting habitat, although marine factors also contribute to this trend (Raphael et al. 2016a, pg. 115).

- While terrestrial habitat amount and configuration (including fragmentation), and the terrestrial human footprint (i.e., cities, roads, development), appear to be strong factors influencing distribution in Zones 2-5; terrestrial habitat and the marine human footprint (i.e., shipping lanes, boat traffic, shoreline development) appear to be the most important factors that influence marine distribution and abundance in Zone 1 (Raphael et al. 2016a, pg. 106).

- Marine bird survival is dependent on the ability to successfully forage in the marine environment. Despite this, it is apparent that the location, amount, and landscape pattern of nesting habitat are the strongest predictors of spatial and temporal distributions at sea during the nesting season (Raphael et al. 2015, pg. 20). Various marine habitat features (e.g., shoreline type, depth, temperature, etc.) apparently have only a minor influence on distribution at sea. Despite this relatively weak spatial relationship, marine factors, and especially any decrease in forage species, likely play an important role in explaining the apparent population declines, but the ability to model these relationships is currently limited (Raphael et al. 2015, pg. 20).

When the marbled murrelet was listed under the Act in 1992, several threats were identified as the likely causes for the species' dramatic decline (57 FR 45328; October 1, 1992) as follows.

- Habitat destruction and modification in the terrestrial environment, from timber harvest and human development, resulting in a severe reduction in the amount of available nesting habitat.
- Unnaturally high levels of predation resulting from forest "edge effects".
- Manmade factors, such as mortality from oil spills and entanglement in fishing nets.
- Existing regulatory mechanisms, such as land management plans, which were considered inadequate to ensure protection of the remaining nesting habitat and reestablishment of future nesting habitat. The regulatory mechanisms implemented since 1992 that affect land management in Washington, Oregon, and California (for example, the Northwest Forest Plan; NWFP), and new gill-netting regulations in northern California and Washington, have reduced these threats (USFWS 2004, pp. 11-12).

However, additional threats were identified by the USFWS's 2009, 5-year review (USFWS 2009b, pp. 27-67) as follows.

- Habitat destruction, modification, or curtailment of the marine environmental conditions necessary to support marbled murrelets, due to elevated levels of contaminants in prey, changes in prey abundance and availability, changes in prey quality, climate change in the Pacific Northwest, and harmful algal blooms that produce biotoxins and cause marbled murrelet mortalities.
- Other human caused factors and stressors in the marine environment, including derelict fishing gear leading to mortality from entanglement, and various forms of disturbance (e.g., lethal and sub-lethal exposures to elevated underwater sound pressure levels caused by impact pile driving and underwater detonations; high vessel traffic).

Conservation Role of the Action Area

The action area in Washington includes the outer marine waters of the Strait of Juan de Fuca, and the nearshore and offshore marine waters of the Washington coast. The action area in Oregon includes the nearshore and offshore marine waters of the Oregon coast.

Marbled murrelets spend most of their lives in the marine environment where they consume a diversity of prey species, including small fish and invertebrates. They occur primarily in nearshore marine waters within 5 km of the coast but have been documented up to 300 km off the coast of Alaska in winter (Nelson 1997, pg. 3). The inland nesting distribution is strongly associated with the presence of mature and old-growth coniferous forests. Marbled murrelets have been detected more than 100 km inland in Washington (70 miles). The inland distribution in the southern portion of the range is associated with the extent of the hemlock/tanoak vegetation zone, which extends 16 to 51 km inland (10 to 32 miles) (Evans Mack et al. 2003, pg. 4).

With consideration for the best available data describing marbled murrelet abundance, distribution, population trends, and reproductive success, the USFWS has concluded that the marbled murrelet populations in the Washington portion of the range currently have little or no ability to self-regulate (as indicated by the significant, annual decline in abundance for Conservation Zones 1 and 2) (USFWS 2019, pg. 12). Populations in Oregon (Zone 3 and part of Zone 4) are apparently more stable, but threats associated with habitat loss and habitat fragmentation continue to occur in those portions of the range. The USFWS expects the species to continue to exhibit further reductions in distribution and abundance into the foreseeable future, largely because threats and stressors present in the marine and terrestrial environments will continue into the foreseeable future (USFWS 2019, pg. 12).

The action area is critically important to marbled murrelet populations in Conservation Zones 1 through 4 (Figure 4 above), and by extension, is also critically important to the rangewide conservation and recovery of the species. The action area provides prey resources that are essential to the health and productivity of marbled murrelet populations in Conservation Zones 1 through 4. The action area also supports individuals from other Conservation Zones and/or British Columbia (i.e., those that seasonally forage and migrate to the north and south, respectively).

The USFWS's recovery plan identifies five marine areas (four in the action area) that support the highest concentrations during the breeding season; these marine areas provide marbled murrelet foraging and loafing opportunities that are regarded as essential and must be protected (USFWS 1997, pg. 135) as follows.

- All waters of Puget Sound and the Strait of Juan de Fuca in Washington, including the waters of the San Juan Islands and river mouths.
- Nearshore waters (within 1.2 miles of the shore) along the Pacific Coast from Cape Flattery to Willapa Bay in Washington, including river mouths.
- Nearshore waters (within 1.2 miles of the shore) along the Pacific Coast from Newport Bay to Coos Bay in Oregon, including Yaquina Bay and river mouths.
- Nearshore waters (within 1.2 miles of the shore) along the Pacific Coast from the Oregon-California border south to Cape Mendocino in northern California, including Humboldt and Arcata Bays, and river mouths (e.g., mouths of the Smith River, Klamath River, Redwood Creek, and Eel River).

The marine environment will play an essential role in the recovery of the marbled murrelet. Protecting the quality of the marine environment is identified in the recovery plan as an integral part of the recovery effort (USFWS 1997, pg. 120). Marbled murrelets spend the majority of their lives in marine areas, usually within five kilometers of the shoreline, where forage fish and other marine prey resources are most abundant (USFWS 1997, pg. 120). If marine areas are degraded and do not provide sufficient prey resources, individual fitness and reproductive success will be reduced.

Climate Change Effects

Marbled murrelets are expected to experience effects of climate change in both their nesting habitat and marine foraging habitat. Natural disturbances of nesting habitat are expected to become more frequent, leading to accelerated habitat losses that may outpace ingrowth even in protected landscapes. Marine food chains are likely to be altered, and the result may be a reduction in food resources for marbled murrelets. Even if food resources remain available, the timing and location of their availability may shift, which may alter marbled murrelet nesting seasons or locations. In addition, health risks from harmful algal blooms, anthropogenic toxins, and perhaps pathogens are likely to increase with climate change.

Within the marine environment, effects on the marbled murrelet food supply (amount, distribution, quality) provide the most likely mechanism for climate change impacts to marbled murrelets. Studies in British Columbia (Norris et al. 2007, entire) and California (Becker and Beissinger 2006, entire) have documented long-term declines in the quality of marbled murrelet prey, and one of these studies (Becker and Beissinger 2006, pg. 475) linked variation in coastal water temperatures, marbled murrelet prey quality during pre-breeding, and marbled murrelet reproductive success. These studies indicate that marbled murrelet recovery may be affected as long-term trends in ocean climate conditions affect prey resources and marbled murrelet reproductive rates. While seabirds such as the marbled murrelet have life-history strategies adapted to variable marine environments, ongoing and future climate change could present changes of a rapidity and scope outside the adaptive range of marbled murrelets (USFWS 2009b, pg. 46).

Summary

The marbled murrelet is generally in decline in the action area (Conservation Zones 1 and 2), and threats and stressors present in the marine and terrestrial environments will continue into the foreseeable future. Marbled murrelet populations in Conservation Zones 1 and 2 and throughout the listed range have low resilience to deleterious population-level effects and are at high risk of continuing or renewed declines. As stated in the Status of the Species section above, Zones 1 through 4 are the four Zones where increased productivity and stable or increasing population size are needed to provide redundancy and resilience that will enable recovery and long-term survival.

Effects of the Action

Effects of the action are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action. (See § 402.17).

Effects of the Action on the Marbled Murrelet

The NSF provided the following supplemental analysis (H. Smith, March 24, 2020, and updated March 15, 2021) describing the characteristics of the proposed airgun array as well as a preliminary analysis of the potential effects of the proposed airgun activities on marbled murrelets. [Note: the original heading format and table and figure numbers for this section were updated for consistency.]

Airgun Characteristics

A 36-airgun array with a total discharge volume of 6600 in^3 is proposed for use by R/V *Langseth* to study the Cascadia Margin. Most energy emitted from airguns is at relatively low frequencies, between 2 and 188 Hz. However, the pulses contain energy up to 500–1000 Hz and some energy at higher frequencies (Goold and Coates 2006; Potter et al. 2007; Hermannsen et al. 2015; Kyhn et al. 2019). Nonetheless, the predominant energy is at low frequencies. The resulting downward-directed pulse from an airgun has a duration of only 10–20 ms (Caldwell and Dragoset 2000). Due to reverberation, the pulse duration as received at long horizontal distances can be greater and background sound levels may be elevated between airgun pulses (e.g., Guerra et al. 2011, 2016; Klinck et al. 2012).

The vessel would be traveling at a speed of ~4.1 knots (2.1 m/s), and the shot interval would be every 37.5 m or ~17 s. The nominal source level of the 36-airgun array is 259 dB re 1 μPa · m (0-peak) or 265 dB re 1 μPa · m (peak to peak). These are the nominal source levels applicable to downward propagation. The effective source levels for horizontal propagation are lower than those for downward propagation when the source consists of numerous airguns spaced apart from one another, as is the case here.

Acoustic Modeling

Mitigation zones for the proposed seismic survey were calculated based on both modeling by Lamont-Doherty Earth Observatory (L-DEO) and using empirical measurements from Crone et al. (2014) from the Cascadia Margin; the methodology used varied with water depth category (shallow, intermediate, deep). Received sound levels have been predicted by L-DEO's model (Diebold et al. 2010) as a function of distance from the 36-airgun array using a 9-m tow depth. This L-DEO modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor). The mitigation radii for intermediate water depths (100–1000 m) were derived from the deep-water ones (>1000 m) by applying a correction factor of 1.5. For shallow water (<100 m), radii were based on empirically derived measurements in the Gulf of Mexico (GoM) with scaling applied to account for differences in tow depth (see Appendix A in the Environmental Assessment [EA]). Table 3 shows the distances at which the 160 dB re 1µPa_{rms} sound level is expected to be received for the 36-airgun array, based on the modeling; this information was presented in the EA.

TABLE 3. Predicted distances, based on modeling, to which sound levels ≥160-dB could be received during the proposed surveys in the Northeast Pacific Ocean.

Source and Volume	**Tow Depth (m)**	**Water Depth (m)**	**Predicted distances (in m) to the 160-dB rms Received Sound Level**
4 strings 36 airguns 6600 in^3	12	>1000 m	6,733
		100–1000 m	10,100
		<100 m	25,494

For deep water, field measurements cannot be used readily to derive mitigation radii, as at those GoM sites the calibration hydrophone was located at a roughly constant depth of 350–500 m, which may not intersect all the sound pressure level (SPL) isopleths at their widest point from the sea surface down to the maximum relevant water depth. Thus, modeled radii have to be used for deep water. However, empirical data from an L-DEO study (Crone et al. 2014) that collected a multichannel seismic (MCS) data set from R/V *Langseth* on an 8-km streamer in 2012 on the shelf of the Cascadia Margin (up to 200 m water depth) could be analyzed to determine in situ sound levels for shallow and intermediate-water depths. This is summarized below as this information was not included in the EA.

Empirical Data for Estimation of Sound Level Distances

Based on Crone et al. (2014; *Estimating shallow water sound power levels and mitigation radii for the R/V Marcus G. Langseth using an 8 km long MCS streamer*), empirical data collected on the Cascadia Margin in 2012 during the COAST survey support the use of the MCS streamer data and the use of Sound Exposure Level (SEL) as the appropriate measure to use for the prediction of mitigation radii for the proposed survey. In addition, this peer-reviewed paper showed that the method developed for this purpose is most appropriate for shallow water depths down to ~200 m. To estimate the distances of different sound levels in shallow and intermediate water depths, we used the received levels from MCS data collected by R/V *Langseth* during the COAST survey (Crone et al. 2014). Streamer data in shallow water collected in 2012 have the advantage of including the effects of local and complex subsurface geology, seafloor topography, and water column properties, and thus allow us to establish mitigation radii more confidently than by using the data from calibration experiments in the GoM (Tolstoy et al. 2009; Diebold et al. 2010).

As shown by Madsen et al. (2005), Southall et al. (2007), and Crone et al. (2014), the use of the root mean square (rms) pressure levels to calculate received levels of an impulsive source (e.g., airgun) leads to undesirable variability in levels due to the effects of signal length, potentially without significant changes in exposure level. All these studies recommend the use of SEL to establish impulsive source thresholds used for mitigation. Here we provide both the actual measured 160 dB_{rms} and 160 dB_{SEL} to demonstrate that for determining mitigation radii in shallow and intermediate water, both would be significantly less than the modeled data for this region.

The entire 160 dB_{SEL} level data are within the length of the streamer and are well behaved throughout this depth profile. The measured sound level data in this area suggest that the 160 dB_{SEL} mitigation radius distance would be well defined at a maximum of 8192 m but that the 160 dB_{rms} would be close to ~11 km (Fig. 1). For a few shots along this profile, the 160 dB_{rms} is just beyond the end of the streamer (8 km). For these shots, extrapolation was necessary. Crone et al. (2014) could only extrapolate the 160 dB_{rms} levels up to a distance of ~11 km (~133% of the length of the streamer). However, the stable 160 dB_{SEL} levels across this interval would support an extrapolated value of not much more than 11 km for the 160 dB_{rms} level given that the 160 dB_{rms} and 160 dB_{SEL} levels track consistently along the profile (Figure 5).

As noted in Table 4 of Crone et al. (2014), the full range of 160 dB_{rms} measured radii for intermediate waters is 4291 m to 8233 m. The maximum 160 dB_{rms} measured radius of 8233 m (represented by a single shot at ~33750 from Fig. 1) was selected for the 160 dB_{rms} measured radius in Table 4. Only two shots in water depths >100 have radii that exceed 8000 m, and there were over 1100 individual shots analyzed in the data; thus, the use of 8233 m as the radius is conservative.

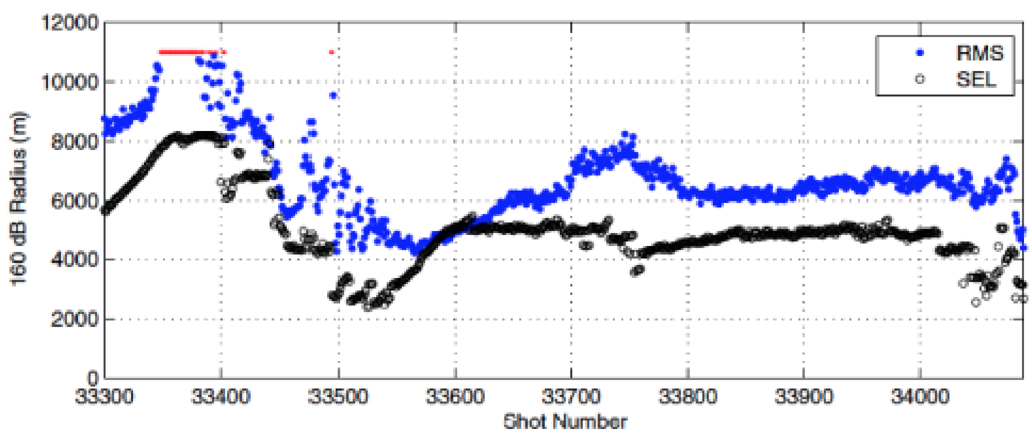

FIGURE 5. Measured radius distances to the 160 dB level for both SEL and rms along line A/T collected in 2012 in Cascadia by R/V *Langseth's* 6600 in^3 airgun array towed at a depth of 9 m (Fig. 12 from Crone et al. 2014). Line A/T extended across the shelf from ~50 m water depth (Shot 33,300), 100 m water depth (Shot # 33,675), out to the shelf break at a depth of 20 0m (~Shot # 34000).

TABLE 4. Comparison of modeled mitigation radii with empirically derived radii from the Cascadia Margin during the 2012 COAST Survey. Radii for both measured 160dB_{RMS} and

160dB$_{SEL}$ are shown with (in red for 160dB$_{RMS}$) and without conversion factor for source tow depth. It was not possible to derive deep water radii from the empirical data; thus, the deep-water radius is estimated to be 6733 m, based on modeling.

Array	Water Depth (m)	Proposed CASCADIA PROJECT RADII (using LDEO Modeling)	COAST PROJECT RADII (using LDEO Modeling)	Predicted Cascadia Project Radii using Empirical Data (Crone et al.2014). 160dB RMS Measured distances w/source depth conversion factor are shown in RED			
		Predicted distances (in m) to the 160-dB RMS Received Sound Level Langseth 6600 cu.in @12m	Predicted distances (in m) to the 160-dB RMS Received Sound Level Langseth 6600 cu.in @9m (COAST CRUISE)	Measured Distance (m) @ 160dB SEL from Figure 1 (Figure 12 - Crone et al., 2014)	Measured Distances (m) @160dB SEL w/Conversion Factor (1.15) from 9m to 12m Source Tow Depth	Measured Distance (m) @ 160dB RMS from Figure 1 (Figure 12 -Crone et al., 2014)	Measured Distances (m) @160dB RMS w/Conversion Factor (1.15) from 9m to 12m Tow Depth
4 strings, 36 airguns, 6600 in3	<100 m	25,494	20,550	8,192	9,421	11000*	12,650
	100 - 1000m	10,100	12,200	5478	6300	8233	9468

*Note: This value is extrapolated from end of 8km streamer. Based on stable SEL values at same shot values, RMS extrapolated value is reasonable approximation

The empirical data collected during the COAST survey on the Cascadia Margin and measured 160 dB$_{rms}$ and 160 dB$_{SEL}$ values demonstrate that the modeled predictions are quite conservative. While we have sought to err on the conservative side for our activities, being overly conservative can dramatically overestimate potential and perceived impacts of the proposed activity.

Evidence from multiple publications including Crone et al. (2014) have argued that SEL is a more appropriate metric for mitigation radii calculations. However, it is important to note that use of either measured SEL or rms metrics yields significantly smaller radii in shallow water than model predictions.

When evaluating the empirical and modeled distances, all the other considerations and aspects of the airgun array still apply including:

- The airgun array is actually a distributed source and the predicted farfield[4] level is never actually fully achieved.
- The downward directionality of the airguns means that the majority of energy is directed downwards and not horizontally.
- Animals observed at the surface benefit from Lloyds mirror effect.
- There is only one source vessel and the entire survey area is not ensonified all at one time, but rather the much smaller area around the vessel.

For these reasons, we ([NSF] have used the mitigation radii based on the empirical data for shallow and intermediate water depths; the deep-water radii are based on modeling (Table 5). Similarly, data collected by Crone et al. (2017) during a survey off New Jersey in 2014 and 2015 confirmed that *in situ* measurements and estimates of the 160-dB distance collected by R/V *Langseth* hydrophone streamer were 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels[3] have confirmed that the L-DEO model generated conservative threshold distances.

TABLE 5. Proposed mitigation zone distances for the proposed seismic survey calculated by modeling by L-DEO and using empirical measurements from Crone et al. (2014) from the

[3] L-DEO surveys off the Yucatán Peninsula in 2004 (Barton et al. 2006; Diebold et al. 2006), in the Gulf of Mexico in 2008 (Tolstoy et al. 2009; Diebold et al. 2010), off Washington and Oregon in 2012 (Crone et al. 2014), and off New Jersey in 2014 and 2015 (Crone et al. 2017). [4] The "farfield" describes a sound field beyond the near field limits described above where the sound pressure level (SPL) drops off at the theoretical rate of 6 dB fore very doubling of distance from the source. This rule of thumb is called the Inverse Square Law.

Cascadia Margin; the methodology used varied with water depth category (shallow, intermediate, deep).

Source and Volume	**Tow Depth (m)**	**Water Depth (m)**	**Distances (in m) to the 160-dB rms Received Sound Level**	**Distance (in m) to the 202-dB Sound Exposure Level**
4 strings 36 airguns 6600 in^3	12	>1000 m 100–1000 <100 m	6,733 9,468 12,650	84

Determination of Cumulative Sound Exposure Levels (SEL_{cum})

The SEL_{cum} for the array was derived from calculating the modified farfield signature. The farfield signature is often used as a theoretical representation of the source level. To compute the farfield signature, the source level is estimated at a large distance directly below the array (e.g., 9 km), and this level is back projected mathematically to a notional distance of 1 m from the array's geometrical center. The User Spreadsheet from the National Oceanic and Atmospheric Administration (NOAA) *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing* was used, but we relied on overriding the default values and calculating individual adjustment factors (dB) based on the modified farfield (see Appendix A of EA). The new adjustment factors in the spreadsheet allow for the calculation of SEL_{cum} isopleths in the spreadsheet and account for the accumulation (Safe Distance Methodology) using the source characteristics (source velocity and duty) after Sivle et al. (2014). Based on a ship speed of 4.1-4.2 kts and a shot interval of 37.5 m, the radius around the vessel at which marbled murrelets could be exposed to sound levels up to 202 dB SEL was estimated to be 84 m (Table 5).

Seabird Hearing

Depending on received levels (largely a function of distance between source and receiver), portions of the sound frequency spectrum (primarily those in the range of 1-5 kHz) generated by airgun discharges and by the vessel's engine would be audible to seabirds below the water surface. Sounds produced by the other acoustic sources (e.g., multibeam echosounder, sub-bottom profiler, Acoustic Doppler Current Profiler) are believed to be well above the upper frequency limit of bird hearing. As a result, these devices should be inaudible to seabirds. The underwater hearing of seabirds (including loons, scaups, gannets, and ducks) was investigated by Crowell (2016), and the peak hearing sensitivity was found to be between 1500 and 3000 Hz. The best sensitivity of underwater hearing for great cormorants was found to be at 2 kHz, with a hearing threshold of 71 dB re 1 μPa_{rms} (Hansen et al. 2017).

Marbled murrelet Distribution

Marbled murrelets are widespread along the Pacific coast and are generally found in nearshore waters, usually within 5 km of shore (Nelson 1997). The population(s) of marbled murrelets in California, Oregon, and Washington has declined by nearly 30% from 23,700 individuals in 2000 to 16,700 individuals in 2010 (Miller et al. 2012). The primary reason for declining populations is the fragmentation and destruction of old-growth forest nesting habitat. Marbled murrelets are also threatened by gillnet fishing, nest predation, and oil spills.

Nesting critical habitat for marbled murrelets consists of forest stands containing large trees with potential nest platforms (including large branches, deformities, mistletoe infestations) at least 10 m in height; high canopy cover is also important for nesting marbled murrelets (USFWS 2016). Although terrestrial critical habitat has been identified in B.C., Washington, and Oregon, no critical marine habitat has been designated for marbled murrelets to date. Marbled murrelet nesting occurs between late March and August, but the birds remain in the waters of that region during the non-breeding season.

Marbled murrelets feed at sea where they forage on small schooling fish and invertebrates in bays and fiords and in the open ocean (Nelson 1997). They forage near the water surface and in the water column, typically at depths <10 m; however, some birds may dive as deep as 27 m or deeper (USFWS 1997). Foraging dives last from 28–69 seconds (USWFS 1997).

Feeding habitat for marbled murrelets is mostly within 1-2 km of shore in waters up to 50-100 m deep (USFWS 1997). the mean offshore distance over a 3-year tracking study was 1.4 km (Hébert and Golightly 2008). Areas >20 km from shore are hardly used by marbled murrelets (Kuletz 2005; Burger et al. 2008), and Lorenz et al. (2017) noted that pelagic environments >30 km from shore are "never used by marbled murrelets". Nonetheless, marbled murrelets have been observed up to 90 km from shore (Kenyon 2009; Adams et al. 2014; Northrup et al. 2008) on rare occasions. Areas with nesting habitat that was closer to shore and in cool waters had greater probabilities of use than other marine habitat (Lorenz et al. 2016). Adams et al. (2014) reported a density of <0.01 marbled murrelets/km^2 for the continental slope, where waters are 200–2000 m deep.

Potential Effects on Marbled murrelets

The effects of sounds from airguns could include one or more of the following: direct effects such as behavioral disturbance, and at least in theory, temporary threshold shift (TTS) or permanent hearing impairment or threshold shift (PTS), and non-auditory physical or physiological effects, as well as indirect effects. However, investigations into the effects of airguns on seabirds are extremely limited. Much of the information presented below is from the Programmatic Environmental Impact Statement/Overseas Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey (June 2011) and Record of Decision (June 2012), referred to here as the PEIS.

Disturbance

There is potential for localized, temporary displacement and disruption of feeding during seismic surveying. However, such displacements could be similar to those caused by other large vessels that pass through the area. Stemp (1985) conducted opportunistic observations on the effects of seismic exploration on seabirds. He did not find any conclusive evidence that seismic surveying affected the distribution or abundance of northern fulmars, black-legged kittiwakes, or thick-billed murres. However, he cautioned that his observations should not be extrapolated to areas with large concentrations of feeding or molting birds. In a more intensive and directed study, Lacroix et al. (2003) investigated the effect of seismic surveys on molting long-tailed ducks in the Beaufort Sea, Alaska. They did not detect any effects of nearshore seismic exploration on molting long-tailed ducks in the inshore lagoon systems of Alaska's North Slope. Both aerial surveys and radio-tracking indicated that the proportion of ducks that stayed near their marking location from before to after seismic exploration was unaffected by proximity to seismic survey activities. Seismic activity also did not appear to significantly change the diving intensity of long-tailed ducks. Neither Stemp (1985) nor Lacroix et al. (2003) observed any bird injuries or mortalities resulting from seismic surveying with airguns. However, African penguins outfitted with GPS loggers showed strong avoidance of preferred foraging areas and had to forage further away and increase their foraging effort when a seismic survey was occurring within 100 km of the breeding colony (Pichegru et al. 2017). However, the birds resumed their normal behaviors when seismic operations concluded.

As it is not possible to determine the distance for the 150 dB re 1 µPa_{rms} rms level from the empirical data, here we can use the conservative modeled 160 dB rms distance as a proxy for shallow water areas. Modeling showed that the 150 dB rms level could be 52.6 km. If the 160 dB rms empirically determined distance is compared to the 160 dB rms modeled distance, it is ~ ½ the size. Thus, we can assume that the empirically derived distance for the 150 dB level would also be ~ ½ of the modeled one, or in this case ~26 km, which aligns with the modeled 160 dB distance of 25.5 km, thus supporting our use of it as a proxy. Sound levels up to 150 dB_{rms} are expected to ensonify nearly all of the marbled murrelet habitat along the coasts of Washington and Oregon (see Fig. 2). Based on a behavioral disturbance radius of 25.5 km, and a vessel speed of 4.1-4.2 knots, it would take the vessel ~7 hrs to travel 51 km or the full diameter of the behavioral disturbance zone. Thus, any location along the coast is expected to be exposed to sound levels >150 dB_{rm} for that amount of time. Also, it is expected that most locations along the coast of Washington could be ensonified only once, but that some locations along the coast of Oregon could be esonified up to two times (during two separate vessel passes) but these passes would occur several days apart [see Description of the Proposed Action, Figure 1].

Using the modeled radii for the 160 dB_{rms} sound level (Table 3), buffers were drawn around all of the transect lines using GIS; the resulting ensonified areas are shown in Table 6. In our analysis, we used within and outside of 8 km as a distance category, as most marbled murrelets are thought to occur within 8 km from shore (as described above). We also used 30 km as a distance category, as marbled murrelets are not expected to occur farther than that offshore (see above). The densities within 8 km from shore are from McIver et al. (2019); densities for areas farther from shore were calculated based on the extent of the marine area and the assumption that ~5% of the marbled murrelet population occurs outside of the areas that are regularly surveyed by USFWS (i.e., farther than 8 km from shore) (Table 6). Population sizes were assumed to be 5600 marbled murrelets for Washington and 11,100 marbled murrelets off Oregon (McIver et al. 2019). Multiplying the ensonified areas with the densities resulted in no exposed marbled murrelets in nearshore waters off Washington, 8,085 exposures in nearshore waters off Oregon, and 458 birds in offshore waters. Thus, we estimate that a total of 8,453 marbled murrelets could be exposed to sound levels equal to or greater than 160 dB_{rms} during the survey.

Table 6. Ensonified areas out to 160 dBrms, and densities for the area off Washington and Oregon.

State	Distance Category	Density (marbled murrelets/km^2)	Ensonified Area (km^2)

Washington	<8 km from coast	1.08[1]	0
Oregon	<8 km from coast	5.34[1]	1514
Washington	8-30 km from coast	0.05[2]	1390
Oregon	8-30 km from coast	0.05[2]	8769

[1]McIver et al. (2019). [2] Based on 5% of the population (835 of 16,700 marbled murrelets) in an area of 16,697 km^2 off Washington and Oregon, between 8-30 km from shore.

However, not all of these individuals would be exposed at the same time and depending on the marbled murrelet's behavior at the time the vessel passes, it may or may not be affected, depending on whether it is foraging or not, as well as other factors. Also, the airguns are expected to operate 24 hours a day off the coast of Oregon, as well as in water >200 m deep off Washington, but marbled murrelets may not forage as much at night (Northrup et al. 2018); in water <200 m deep off Washington, seismic operations would only occur during daytime. In order to determine the risk of an individual being exposed and behaving in response to increased sound levels, it would be important to know the activity budget of individuals (time spent diving/foraging per day). Also, the sound levels are likely to be reduced near the water surface where marbled murrelets forage (typically within 10 m of the surface). In addition, at distances far from the vessel (>8 km) and near the coast, ambient noise from other vessel traffic would be substantial, and airgun sounds would not be expected to add much additional noise.

Acoustic Effects

Marbled murrelets feed by diving to depths of several meters or more, and alcids often escape from approaching boats by diving. Therefore, it is theoretically possible, though considered highly unlikely, that during the course of normal feeding or escape behavior, some birds could be near enough to an airgun to experience a threshold shift by a pulse if they dove relatively deep (>10 m) directly beneath the array. However, there is no evidence for such effects if they occur, and there is no specific information available about the circumstances (if any) where this might occur. Furthermore, it is considered highly unlikely that marbled murrelets would dive near enough to a sound source to experience hearing impairment. Lloyd's Mirror Effect further reduces the potential for PTS and TTS. Lloyd's Mirror Effect serves to reduce acoustic energy (i.e., sound levels) at and just below the water surface where seabirds occur and/or feed. In addition, the received level at the ears of the marbled murrelet would be a lot lower than the level in the water because there is a 'bubble curtain' around the birds held by their feathers.

Although there appears to be minimal risk of an acoustic effect or injury on diving marbled murrelets, it was determined how many marbled murrelets may occur within the zone around the vessel where sound levels could be loud enough (202 dB SEL) to cause potential injury. Within this distance (~84 m; see above), it is thought there is potential risk for injury or PTS. As all vessel transects occur farther than 8 km from shore (and farther than 21 km from shore off Washington), sounds at this level are not anticipated to impact the majority of habitat used by marbled murrelets along the coasts of Washington and Oregon. Thus, no injurious effects are expected to occur within 8 km from shore, where densities are highest. Although most marbled murrelets occur within 2 km from shore (as noted above), we are using 8 km here, as that is the maximum distance from shore that marbled murrelet surveys occur (Raphael et al. 2007). In addition, USFWS noted that marbled murrelets generally occur within 8 km from shore and in water <60 m deep.

Using GIS, the 84 km buffer was drawn around all proposed seismic transects in U.S. waters. None of the ensonified area is located within 8 km from shore. If the offshore density (0.05 marbled murrelets/km^2) is multiplied by the area expected to be ensonified during the survey at a distance of 8 to 30 km from shore (106 km^2), that results in an estimate of 5 marbled murrelets that could potentially be exposed to sound levels of 202 dB SEL or greater.

Depending on the marbled murrelet's behavior at the time the vessel passes, it may or may not be affected, depending on whether it is foraging or not, as well as other factors. Also, the airguns are expected to operate 24 hours a day off Oregon and in water >200 m deep off Washington, but marbled murrelets may not forage as much at night (Northrup et al. 2018). In order to determine the risk of an individual being exposed and behaving in response to increased sound levels, it would be important to know the activity budget of individuals (time spent diving/foraging per day). Also, the sound levels are likely to be reduced near the water surface where marbled murrelets forage (within 10 m of the surface), and because there is a 'bubble curtain' around the birds held by their feathers. For these reasons, even though 9 takes were calculated based on density and area potentially ensonified, injurious takes would not be anticipated by the proposed action.

Indirect Effects

If airguns disorient, injure, or kill prey species, or otherwise increase the availability of prey species to marbled murrelets, a seismic survey could attract birds to within ~10 m of active airguns. Birds very close to an airgun may be at risk of induced PTS or other injury due to the intense pressure pulses of the airgun discharges at such close range. However, available evidence from other seismic surveys utilizing airguns has not shown a pattern of fish (or other prey) kills from airguns (see Section 3.3, in PEIS). Also, during thousands of hours spent conducting biological observations from operating seismic vessels, observers have seldom seen birds being attracted to an airgun array.

Summary

There are no scientific data indicating or suggesting that seabirds are adversely affected by seismic airguns or other sound sources used during the proposed seismic surveys. Moreover, thousands of hours of observational data by protected species observers during numerous seismic surveys throughout the world suggest that seabirds do not remain in the water near the airgun array where they would be at potential risk of injury. No marbled murrelets, or impacts to this species, were observed during a similar seismic survey conducted in 2012 or a low energy survey conducted in 2017. In decades of seismic surveys carried out by R/V *Langseth* and its predecessor, the R/V *Ewing*, observers and other crew members have seen no seismic sound-related seabird injuries or mortality. In addition, the Lloyd's Mirror Effect serves to reduce acoustic energy (i.e., sound levels) at and just below the water surface where seabirds occur and/or feed. Thus, the potential for acoustic sources associated with the proposed seismic surveys to injure seabirds is considered insignificant. Although these activities could affect marbled murrelet behavior above the water, such effects are considered short-term and negligible to individuals and populations. The PEIS concluded that there could be transitory disturbance, but that there would be no significant impacts of NSF-funded marine seismic research on seabirds or their populations. The acoustic source would be powered or shut down in the unlikely event an ESA-listed seabird was observed diving or foraging within the designated EZ.

[End of NSF analysis.]

Additional USFWS Analysis

The following analysis addresses USFWS assumptions, analysis, and conclusions specifically with regard to observer success, sound impacts, marbled murrelet foraging behavior, marbled murrelet density estimates, and resulting effects that vary from that of the NSF analysis above.

The NSF analysis above provides an exposure analysis and estimates the number of marbled murrelets that may be exposed to SPLs that are likely to cause physical injury or behavioral responses. The below analysis will address whether that exposure is likely to lead to actual adverse effects and take of marbled murrelet. The Service does not agree with the NSF assessment that there is minimal risk of an acoustic effect or injury on diving marbled murrelets, that 202 dB SEL is expected to cause potential rather than actual injury, or that no injurious effects are expected to occur within 8 km from shore where marbled murrelet densities are highest. Furthermore, the Service does not concur with the NSF assessment that there is no scientific data indicating or suggesting that seabirds are adversely affected by seismic airguns. Nor does the Service concur with the NSF conclusion that the potential for acoustic sources associated with the proposed seismic surveys to injure seabirds is considered insignificant.

Injurious Effects of Underwater Sound Pressure

Data specific to seabirds is primarily limited to evaluations of the effects of underwater blasting and seismic testing (Yelverton and Richmond 1981, p. 3; Cooper 1982; Stemp 1985; Flint et al. 2003; Lacroix et al. 2003). Monitoring of seabird response to pile driving for bridge and ferry terminal projects in Washington has generated some information on seabird responses to pile driving and has documented behaviors that could be indicative of physiological effects. During replacement of the Hood Canal Floating Bridge a pigeon guillemot (*Cepphus columba*) dove within 75 meters of impact pile driving, surfaced quickly, was shaking its head, and appeared to have difficulty getting airborne (Entranco and Hamer Environmental 2005,p. 21). In 2007, monitoring staff at the Anacortes Ferry Terminal replacement project detected a marbled murrelet within 20 meters of active pile driving. The bird was behaving aberrantly. It drifted very close to shore, was listing to one side, and was paddling with only one foot. While most seabirds were leaving the area during pile driving this bird did not dive or fly. After a few minutes the marbled murrelet attempted to fly but had difficulty getting airborne (WSF 2007, pp. 4-57). These observations suggest how affected seabirds might behave when exposed to elevated underwater sound pressure levels. It is impossible to estimate the exact "dose" of underwater sound pressure that these observed seabirds might have received, other than to note that they were detected within a zone where we would have expected exposure to injurious levels of underwater sound.

Faced with the absence of controlled studies of underwater sound and pressure effects from explosions specific to seabirds we utilize evaluations of the effects of other types of underwater sounds on a variety of vertebrate species provide the basis for evaluating the effects of the high SPLs generated by pile driving on marbled murrelets. High levels of underwater sound are known to have negative physiological and neurological effects on a wide variety of vertebrate species (Yelverton et al. 1973; Yelverton and Richmond 1981; Gisiner et al. 1998; Cudahy and Ellison 2002; U.S. Department of Defense 2002; Hastings and Popper 2005). Experiments using underwater explosives found that rapid change in underwater SPLs resulted in internal hemorrhaging and mortality in submerged mallards *(Anas platyrynchos)* (Yelverton et al. 1973, p. 49). During seismic explorations, it has been noted that seabirds were attracted to fishes killed as a result of the seismic work (Fitch and Young 1948; Stemp 1985). Fitch and Young (Fitch and Young 1948) found that diving cormorants were consistently killed by seismic blasts, and pelicans were frequently killed, but only when their heads were below water.

In general, risk of injury from exposure to underwater SPLs appears related to the effect of rapid pressure changes, especially on gas-filled spaces in the bodies of exposed organisms (Turnpenny et al. 1994; Gisiner et al. 1998, p. 61). Examples of gas-filled structures in vertebrate species are swimbladders, bowel, sinuses, lungs, etc. As a sound travels from a fluid medium into these gas-filled structures there is a dramatic drop in pressure which can cause rupture of the hollow organs (Gisiner et al. 1998, p. 61). Biologically, key variables that factor into the degree to which an animal is affected include size, anatomical variation and location in the water column (Gisiner et al. 1998, p. 61). Observation of foraging marbled murrelets during impact pile driving at one project in Washington revealed that marbled murrelets will come fairly close (within 300 m) to active pile driving operations and continue to dive and forage despite elevated underwater sound (Entranco and Hamer Environmental 2005), thus there is a potential for exposure to injurious SPLs.

Injuries from high underwater SPLs can be thought of as occurring over a continuum of potential effects ranging from mortality to sub-lethal physical effects including TTS. At the most severe end of the spectrum, direct mortality or obvious injuries can occur. .

In July 2011, a Science Panel recommended thresholds for marbled murrelets for onset of non-injurious TS in hearing, onset of auditory injury, and onset of non-auditory injury (barotrauma) (SAIC 2011). In March 2012, in response to the lack of data regarding non-injurious threshold shift (TS) and masking effects that occur to marbled murrelets from pile driving, the Service and the Navy convened Science Panel II to evaluate the onset of non-injurious TS (SAIC 2012). Thresholds recommended were:

- Non-injurious TS of 187 dB SEL re: 1 µPa2-sec
- Auditory injury threshold of 202 dB SEL re: 1 µPa2-sec
- Barotrauma at 208 SEL re: 1 µPa2-sec

In the absence of established thresholds related to effects from underwater explosions, the Service has in the past used these thresholds, derived specifically for pile driving, for the few consultations and/or technical assistance recommendations provided for projects involving explosives.

For purposes of this analysis, effect thresholds for underwater explosions are used because application of the pile-driving effect thresholds is not entirely appropriate. While both explosive and airgun stressors differ both in magnitude and the mechanism of effect, explosives more closely emulate airgun effects. Like an underwater explosion, an airgun produces a pressure wave that radiates quickly from the detonation site. However, the strength of this wave depends on the type and amount of explosive force, the location of the airgun in the water column, and the distance from the source (the strength of the airgun pressure wave dissipates with increasing distance). The typical blast pressure wave from an explosive source consists of an instantaneous increase of the peak pressure, followed by a slower (but still very rapid) logarithmic decrease to ambient pressure.

The pressure wave can be displayed as a waveform that describes the pressure-time history, where time is measured in milliseconds or seconds and pressure is measured in micropascals (μPa).

Underwater exposure to explosions can result in barotrauma, mortality, and auditory damage, but severity of injury may vary based on type of explosion and distance from the explosion. For example, if animals are close enough to the detonation, resulting SPLs may cause injuries to lungs, livers, eyes, gastrointestinal tract, ears, kidneys, air sacs and other organs. The animals' proximity to the explosion will influence the severity and nature of their injuries. Explosive impulses behave differently underwater than in the air because of the different properties of air versus water. Sound travels much faster underwater than in air, so the potential "areas where injury may occur" or "ranges to thresholds" are different when explosions occur in the air versus underwater. Animals will be similarly injured by exposure to an explosion depending on 1) their physiological characteristics, 2) proximity to the explosion, 3) charge weight of the explosive and the energy released upon detonation, and the 4) medium the explosion occurs in (air or water, or both).

When animals are exposed to explosions, behavioral responses can range from stress to avoidance or fleeing the area. Allostasis is the process through which organisms maintain stability by actively adjusting behaviorally and physiologically to both predictable (e.g. seasonal changes) and unpredictable events (e.g. storms, predation) (Korte et al. 2005; Mcewen and Wingfield 2003). A classic stress response begins when an animal's central nervous system perceives a potential threat to its homeostasis, thereby triggering a biological response that consists of a combination of behavioral responses, autonomic nervous system responses, and neuroendocrine responses (Buchanan 2000). When stress responses are repeated or chronic, allostatic loading occurs. Allostatic load refers to the cumulative wear and tear on the body as adrenal hormones, neurotransmitters, or immuno-cytokines are released in response to the event. The benefits of allostasis and the costs of allostatic load produce trade-offs in health and disease. In the case of many stressors, an animal's first and most economical response (in biotic terms) is behavioral avoidance of the potential stressor or avoidance of continued exposure to a stressor. An animal's second line of defense to stressors involves the autonomic nervous system and the classical "fight or flight" response which produces changes in heart rate, blood pressure, and gastrointestinal activity (Buchanan 2000; Korte et al. 2005; Mcewen and Wingfield 2003) that humans commonly associate with stress. These responses are relatively short in duration and may or may not involve significant long-term effects on an animal's fitness. When an animal does not have sufficient energy reserves to satisfy the energetic costs of a stress response, energy resources must be diverted from other biotic functions, which, in turn, impair those functions that experience the diversion. For example, when a stress response diverts energy away from growth in young animals, those animals may experience stunted growth. A stress response diverts energy away from egg production, an animal's reproductive success and its fitness may suffer.

The behavioral and physiological reactions to short- versus long-term stress can vary in extent and consequence. The rapid onset of an unpredictable event, such as a predatory attack, will bring on stress responses that are designed to aid an animal immediately. Stress continuing over longer periods (i.e. days to weeks) may result in deleterious chronic effects like increased susceptibility to fatigue and disease (Buchanan 2000).

Relationships between the physiological response mechanisms, animal behavior, and the costs of stress responses have been documented in seabirds (Holberton et al. 1996; Hood et al. 1998; Kitaysky et al. 1999) and a variety of other vertebrates (Jessop et al. 2003; Krausman et al. 2004;

Romano et al. 2004; Smith et al. 2004a; Smith et al. 2004b). These stress responses are expected from exposure to the following events in which multiple-per-day activities occur; detonations, helicopters in marine waters, and the overflights occurring over nesting habitat in the terrestrial environment. We anticipate that when birds experience permanently reduced hearing sensitivity (TS) or repeated exposure to detonations, they may experience additional physiological effects, including increased risk of predation, reduced reproductive success, and reduced foraging efficiency. Marbled murrelets experiencing TS may not be able to detect biologically relevant sounds such as approaching predators or prey, and/or hear their mates or young attempting to communicate. Marbled murrelets that lose their hearing sensitivity are at increased risk of predation and reduced foraging efficiency. Some affected marbled murrelets may regain some or all of their hearing sensitivity; however, they are still temporarily at risk while experiencing TS

The NSF use of airguns will be repetitive but interspersed over a large area. The stressors associated with explosives are typically short in duration. In the event that marbled murrelets are exposed to airguns and not injured or killed, we expect that they will respond with a startle response, flushing, and/or avoidance behaviors (i.e., diving, or leaving the area). Whether these behavioral responses result in a measurable effect to individuals depends largely on the duration of the exposure.

Behavior of Compressed Air Seismic Sources

It is important to acknowledge that "airguns" are not guns in that they do not produce an explosive type of force, and while airguns do emit high SPLs, they do not produce the same energy as a typical explosion (e.g., from ordinance), nor in this case are they used in open air; rather they are more accurately characterized as "compressed air underwater seismic sources." Typically, a compressed air source (airgun) has two air chambers around a piston. Air from one chamber is redirected, pushing the piston out of the way and allowing the release of air which forms a bubble, thereby generating sound created by the expansion and contraction of the bubble (Gisiner 2016, pg. 11). However, the bubble has little to do with the propagation of the sound; rather most of the acoustic energy coming from the compressed air source occurs the fraction of a second before the air expands (Gisiner 2019, entire). The compressed air pushing water out of the way initiates the sound or pulse. A directed pulse of air (or sound) is only achieved when multiple airguns are configured in an array (Massa 1989, entire) combining the pulses from multiple sources and has the effect of cancelling out high frequency sound (Gisiner 2019, entire). While the sound is directed at the sea floor, lateral sound is also expected at multiple low frequencies. The sound propagation effects from a compressed air source behave differently than that of an underwater ordinance explosion or pile-driving in that sound levels near the sound source are relatively "slow" and do not produce a shock wave compared to that of an explosive or pile strike (Gisiner 2019, entire). Lack of a significant shock wave limits the barotrauma effect on animals compared to explosives or pile-driving. The sound also tends to spread out and becomes less "peaky" over distance, which has the effect of minimizing the impact on "masking" the ability of animals to communicate (Gisiner 2019, entire). The seismic source is focused on generating low frequency energy, well below the hearing limit of most animals. Therefore, impacts from the seismic sound source result primarily from the particle motion of the pulse nearest to the source (Gisiner 2019, entire). In the water column, as the sound moves further away from the source, it attenuates significantly from a sharp pulse to a tone (Gisiner 2019, entire). These differences between explosive ordinance and airgun effects are expected to affect exposure distances and level of injurious effect. However, the SPLs produced by airguns have been shown to cause significant injury to seabirds at close range, and the Service concludes marbled murrelets exposed to the SPLs referenced above are reasonably likely to be injured or killed.

Observer Success

During a 2019 seismic survey of the Axial Seamount (RPS 2019, pg. 3), which is located within the action area of the proposed action herein, there were no sightings of protected ESA-listed seabirds. However, the likelihood of listed seabird presence and risk of exposure is exponentially greater for the proposed west coast seismic survey because the scope of this action is much greater (6,540 km of transect lines covered for 37 days of seismic operations). Furthermore, due to the detectability factors discussed above and below, the lack of observed marbled murrelets during prior surveys does not sufficiently predict the exposure risk. Marbled murrelets could be foraging in the area of greatest sound/impact when the operations are within their marine habitat use areas. Survey activities are operating 24 hrs per day, with only passive acoustic monitoring during hours of darkness. Passive acoustic monitoring does not detect seabirds. We know that marbled murrelets primarily forage at night, in particular we know that adults feeding chicks are obtaining fish prior to predawn flights inland during the breeding season (when this project is occurring). Operations can occur in sea conditions (> Beaufort sea state 2) that result in reduced ability of observers to detect marbled murrelets. Marbled murrelets are unlikely to be detected during nighttime operations (pre-dawn and post-sunset foraging times) and may go undetected by observers during daytime operations; power down/shut down procedures would not occur when marbled murrelets go undetected. Generally, detection of marbled murrelets will be limited by vessel speed, visibility, sea state, observer experience and the number of observers, and observations can be expected to drop off with distance (Raphael et al. 2007; Mack and Raphael 2002; Becker et al. 1997). These assumptions suggest that the validity of marbled murrelet density survey results and observer detection success may be enhanced if more observers are involved. Hoekman et al. (2011) recommend the use of two observers, periodic calibration of detection near the transect center line and its incorporation into density estimates, and the use of skilled observers coupled with analytic methods to account for unidentified marbled murrelets.

It is likely in relatively good conditions that the observers should be able to effectively monitor and implement shut down procedures in the zone where the greatest potential for marbled murrelet injury may occur at a distance of ~84 m from the source where they would be exposed to sound levels of 202 dB SEL or greater sound levels at distances closer to the source. However, detection success is expected to be limited in poor visibility conditions when marbled murrelets may be most actively foraging (twilight and dawn).

NSF also claims that thousands of hours spent conducting biological observations from operating seismic vessels, observers have seldom seen birds being attracted to an airgun array. While we find it reasonable to assume birds may not be attracted to an airgun array, particularly one in operation, it is reasonable to assume birds would be attracted to the vessel lighting. Under the proposed action, the vessels will have downward pointing lighting which is expected to limit physical seabird interactions with the vessels. While observers will be present on the R/V *Langseth* to make note of any seabird interactions with the vessel, the R/V *Oceanus* would not be involved in the seismic survey other than instrument deployment/retrieval and this work will be done when the vessel is in a stationary position. On that basis, we do not anticipate significant adverse effects resulting from marbled murrelet interactions with the R/V *Oceanus*. However, it is possible that a very limited number of marbled murrelets that may be present could be attracted to and disoriented by vessel lighting, resulting in collisions and potential injury. In the event of such events, we anticipate a likelihood that a marbled murrelet will be handled by trained observers if it becomes injured and unable to fly away on its own. Although we cannot predict to what extent vessel/marbled murrelet interactions may occur, if at all, observers onboard the R/V *Langseth* will be expected to report any such instances. Based on the above discussion, the Service anticipates the ability of the observer program to minimize marbled murrelet exposure to injurious effects from airguns will have limited success.

Influence of Climate on Action Affects and Prey Availability

Variability in winds, sea surface temperatures, and sea level pressures affect upwelling and marine productivity in the CCS. Year-to-year variability (e.g., El Niño) and longer-term regime shifts (e.g., Pacific Decadal Oscillation) can have consequences for seabird diet and foraging areas. During strong El Niño events, coastal upwelling winds are reduced, there is an intrusion of offshore subtropical water, surface waters are warmer and more nutrient-poor than usual, and there can be dramatic declines in primary and secondary production that can lead to poor recruitment, growth, and survival for many resident species. It is common to have northward range extensions of many tropical species during El Niño events. During La Niña events, the reverse is generally true, with colder, more nutrient-rich waters present. Many studies have shown that reliance on different suites of prey species due to environmental conditions can impact seabird productivity (e.g., Ainley et al. 1995, Sydeman et al. 2006, Wells et al. 2008, Wolf et al. 2009, Cury et al. 2011, Thompson et al. 2012). In general, cold water events or cold ocean phases have been linked to greater prey availability for breeding seabirds (Ainley et al. 1995, Veit et al. 1997, Hyrenbach and Veit 2003, Ainley and Hyrenbach 2010), though a combination of ocean processes operating at various temporal and spatial scales ultimately determine foraging opportunities. The 2020-2021 La Niña event appears to have peaked in October-December as a moderate strength event (WMO 2021, pg. 1). The latest forecasts for waters off Oregon and Washington suggest upwelling, surface temperatures, and bottom oxygen will return to near "characteristic" or normal conditions by the April-June 2021 season (WMO 2021). Lower sea surface temperatures and strong upwelling events have strong positive influences on fish populations (Desimone 2016). Marbled murrelets are likely to forage farther from nesting sites during El Niño years when prey availability is low for reasons other than a lack of upwelling (Becker and Beissinger 2003). Given this project will be occurring from late-May through July of 2021, it is reasonable to suggest that relatively neutral or improved nearshore foraging conditions will be present for the marbled murrelet during this time frame due to the lack of a negative El Niño effect on these resources, thereby reducing the potential for higher exposure levels predicted by NSF. While not expected to eliminate significant marbled murrelet exposure to SPLs, it is reasonable to assume a greater concentration of marbled murrelets are likely to be foraging within nearshore waters and further away from the sound source.

NSF makes a somewhat misleading claim that available evidence from other seismic surveys utilizing airguns has not shown a pattern of fish (or other prey) kills from airguns. While research has not shown fish mortality from airguns, temporary threshold shifts (hearing loss) have been demonstrated repeatedly (Popper et al. 2005, pg. 1; Song et al. 2008, pg. 1), and these studies cannot not be extrapolated to other fish species and or exposure to a larger number of airgun shots in deeper water and over a longer period of time (Popper et al. 2005, pg. 1). As such, the primary concern with airguns and forage fish availability for marbled murrelets is not mortality, but the temporary loss of hearing (TS) in the affected fish causing a behavioral response by the fish, such as diving into deeper water until the sound source has diminished. This in turn could lead to reduced overall marbled murrelet foraging success rates, which is likely to increase the likelihood of also negatively affect breeding success (reduce individual fitness). Overall, while it is likely marbled murrelet foraging bouts are likely to be interrupted when birds are exposed to significant SPLs, the effects of the proposed action on prey availability is expected to be temporary and limited.

Likelihood of Exposure and Response to Effects of Airguns

In developing their exposure estimates, the NSF analysis does not consider the potential for reduced exposure due to shut down procedures should a marbled murrelet be detected, thereby assuming only a potential for successful detections. Marbled murrelets forage near the water surface and in the water column, and as mentioned in the NSF analysis above, typically at depths <10 m. However, marbled murrelets may dive as deep as 27 m or deeper (USFWS 1997, entire). It is possible they are capable of diving to a depth of 47 m (157 ft) based on their body size and diving depths observed for other alcid species (Mathews and Burger 1998, p. 71). The NSF analysis also suggested the sound level received at the ears of the marbled murrelet would be a lot lower than the level in the water because there is a 'bubble curtain' around the birds held by their feathers. The Service concludes this factor may provide far more limited protection than appears to be presumed by the NSF, it remains likely that some marbled murrelets are likely to be exposed to significant injurious effects when diving within 84 m of airgun operations. However, while not proposed by the NSF, research has shown that an induced bubble curtain concentrated around the air-gun ports could be an efficient and practical solution to reduce the high-frequency acoustic emission from air guns (Wehner and Landro, 2020, pg. 1; Teachout, 2012, entire).

Permanent Injury or Mortality - Using the 84 km buffer drawn around all proposed seismic transects in U.S. waters where sound levels would be 202 dB SEL or greater, NSF asserted none of the ensonified area is located within 8 km from shore. NSF used this information to estimate 5 marbled murrelets would be potentially exposed based on their offshore density (0.05 marbled murrelets/km^2) multiplied by the area expected to be ensonified during the survey at a distance of 8 to 30 km from shore (106 km^2). Then NSF inexplicably suggested that their exposure analysis results indicated 9 potential takes based on marbled murrelet density and area potentially ensonified, and that injurious takes would not be anticipated by the proposed action. We have to assume the "9" takes was a typo, and the "takes" would have been more correctly assessed by NSF as the number of birds potentially exposed to adverse effects that may lead to incidental take; and although exposure does not directly extrapolate to an adverse effects leading to incidental take, NSF offers no support for their finding that this level of exposure would not result in any injurious effects. Furthermore, the NSF failed to acknowledge the proposed action would occur in waters 60 to100 m deep (only off a portion of the coast of Oregon), well within the area known to be commonly used by marbled murrelets likely exposing a greater proportion individual birds there to 202 dB SEL or greater.

These exposure estimates are offset by the fact that not all marbled murrelets are on the water at all times, not all marbled murrelets on the water will be diving, and birds some may simply move away from the sound source. However, based on the above information and analysis, we believe it is reasonably likely that one or more marbled murrelets across the entire survey area are likely to be exposed significant injury due to high SPLs, but this level of impact will not significantly reduce marbled murrelet numbers or distribution in the action area or range wide.

Temporary Injury or Behavioral Changes - Areas may be ensonified more than once and any single point may be ensonified at or above the 160 dB behavioral response threshold for a maximum of 6.5 hours. The Service established thresholds for onset of behavioral changes to marbled murrelets from underwater explosions at 150 dB. However, the NSF were unable to provide model results to the 150 dB level as the overly conservative inputs combined with the exponential factoring result in exaggerated and unrealistic results. The NSF cited strong empirical data that supports analysis to the 160 dB isopleth and noted the empirical data does not readily support deriving the 150 dB isopleth. Also, given that the behavior of underwater compressed air explosions is less violent compared to the detonation of underwater ordinance or pile-driving, the exposure threshold for significant marbled murrelet behavioral changes in response to compressed air emissions from airguns at 150 dB appears reasonable if not conservative. Marbled murrelets that experience TS from exposure to airgums at 150 dB are expected to have damaged hair cells in their inner ears and, as a result, may not be able to detect biologically relevant sounds such as approaching predators or prey, and/or hear their mates or young attempting to communicate. Marbled murrelets that lose their hearing sensitivity are at increased risk of predation and reduced foraging efficiency. Some affected marbled murrelets may regain some or all of their hearing sensitivity; however, they are still temporarily at risk while experiencing TS. Even birds not experiencing TS are likely to experience interrupted foraging bouts or resting attempts, which creates a likelihood of injury by significantly disrupting normal behaviors (as a result of their diving repeatedly or vacating the area). Foraging efficiency is likely to be reduced, and energy expenditures are likely to be increased above normal when they flush and/or relocate out of the area. Marbled murrelets are also likely to increase their diving efforts in response to these lost foraging opportunities, or to replace prey dropped or swallowed, or to escape from perceived predator.

NSF estimates that a total of 8,453 marbled murrelets may be potentially exposed to sound levels equal to or greater than 160 dBrms during survey operations. This level of exposure is based on prior marbled murrelet density estimates that typically vary across years and are subject to assumptions as well. Furthermore, a behavioral response to exposure at these sound levels may not always directly translate to adverse impacts because many of these responses are expected to be insignificant. Although marbled murrelets may not generally be expected to move away when approached by an oncoming vessel or increasing sound levels, it is not unreasonable to assume a number of birds may simply move away from the oncoming sound source as it comes closer and the airguns are firing at short intervals. As discussed above, except in the hours before sunrise and after sunset, nesting marbled murrelets are not expected to be on the water at night. It is not reasonable to assume all 8,453 potentially exposed marbled murrelets will be on the water 24 hours per day, or for those that are on the water, diving 24 hours per day, as they may spend substantial time periodically loafing. For these reasons, during the course of the survey it is unlikely that all 8,453 marbled murrelets will be exposed in a manner that results in significant impacts to individual birds from behavioral changes that may temporarily reduce foraging or reproductive success. However, for a subset of marbled murrelets, it is reasonable to assume exposure will lead to a likelihood of adverse behavioral effects.

Individual marbled murrelets that experience TS from exposure to explosions are expected to have damage to the hair cells in their inner ears and may not be able to detect biologically relevant sounds such as approaching predators or prey, and/or hear their mates attempting to communicate. Birds with reduced hearing sensitivity are at increased risk of predation and reduced foraging efficiency. Some birds may regain some or all of their hearing sensitivity; however, they are still temporarily at risk while experiencing TS. Additionally, marbled murrelets that are exposed to explosives but do not experience TS may respond by flushing or temporarily ceasing to forage; however, these birds are expected to return to normal behaviors in a short period of time. For individual marbled murrelets that are exposed to explosions but not injured or killed, we expect a startle response, flushing, or avoidance (i.e., diving, or leaving the area).

For uninjured individuals exposed to single unwater explosive events, these responses would be short term and we would not expect significant disruptions to their normal behavior that would create a likelihood of injury. However, since the seismic survey will result in repeated SPLs in close proximity along a transect, it may result in significant disruptions to a marbled murrelet's normal foraging behavior, potentially reducing individual fitness or their ability to feed a chick. As such foraging success may be temporarily reduced for birds that are actively foraging in areas where the proposed action is producing sound at or above the 160 dB behavioral response threshold. However, due to the unpredictable variables discussed above, the actual number of marbled murrelets likely to be adversely affected in this manner is difficult to estimate with any credible precision. Therefore, we anticipate the number of marbled murrelets adversely affected is likely to be much less than the number potentially exposed as calculated by NSF in the above analysis.

Effects of other Acoustic Sources

In addition to the operations of the airgun array, a multibeam echosounder (MBES), a sub-bottom profiler (SBP), and an Acoustic Doppler Current Profiler (ADCP) would be operated from R/V *Langseth* continuously during the seismic surveys, but not during transit to and from the survey area. The R/V *Oceanus* would operate a single-beam dual-frequency echosounder (4 and 12 kHz) and an ADCP.

The NSF EA and the PEIS did not indicate there was a potential for effects from use of MBES, SBP and ADCP on seabirds, focusing primarily on marine mammals, sea turtles and invertebrates (NSF 2019; USGS 2011). MBES instruments have been used to track fish schooling, detection of deep-sea animals, and predator-prey interactions of marine animals (Williamson et al 2016, entire; Dunlop et al. 2018, entire; Waggitt et al. 2016, entire). The PEIS suggested sounds produced by the MBES, SBP, and ADCP are believed to be well above the upper frequency limit of bird hearing, suggesting these devices should be inaudible to seabirds, but due to the lack of underwater audiograms for seabirds, this cannot be known with certainty (USGS 2011).

The ocean floor would be mapped with the Kongsberg EM122 MBES. The Kongsberg EM122 MBES operates at 10.5–13 kHz and is hull-mounted on the R/V *Langseth*. The maximum source level is 242 dB re 1 μPa·rms. Each ping consists of eight (in water >3,281 ft [1,000 m] deep) or four (<3,281 ft [1,000 m]) successive fan-shaped transmissions, each ensonifying a sector that extends 1° fore–aft. Continuous-wave signals increase from 2 to 15 ms long in water depths up to 8,530 ft (2,600 m), and FM chirp signals up to 100 ms long are used in water >8,530 ft (2,600 m) in depth. The successive transmissions span an overall cross-track angular extent of about 150°, with 2-ms gaps between the pings for successive sectors. The high frequency sound emitted by the MBES (10.5-13 kHz) is expected to be within the hearing range of marbled murrelets (10 and 11.5 kHz, see Nelson 1997; Sanborn et al. 2005; SAIC 2012). Furthermore, the maximum source level of 242 dB is well within the range (202 dB) expected to cause similar auditory and other physical injuries to marbled murrelets as described above for the airguns, so marbled murrelets diving near the source are likely to be significantly affected. However, depending on the distance the airgun array is towed behind the vessel (50-200 m) the effects of the airguns on marbled murrelets at the source could be greater.

The ocean floor would also be mapped with the Knudsen 3260SBP which transmits a beam as a 27° cone directed downward by a 3.5-kHz transducer in the hull of the R/V *Langseth*. The nominal power output is 10 kilowatts (kW), but the actual maximum radiated power is 3 kW or 222 dB re 1 µPa-m. The ping duration is up to 64 ms, and the ping interval is 1 s. A common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause. The low frequency sound emitted by the SBP is not withing the hearing range of marbled murrelets (10 and 11.5 kHz, see Nelson 1997; Sanborn et al. 2005; SAIC 2012), though the maximum sound source level of 222 dB is well within the range (202 dB) expected to cause similar physical injuries to marbled murrelets as described above for the airguns, so marbled murrelets diving near the source are likely to be significantly affected. However, the exposure is mitigated by the narrowly directed beam (27° cone), and depending on the distance the airgun array is towed behind the vessel (50-200 m) the effects of the airguns on marbled murrelets at the source could be greater.

An ADCP would be used to calculate speed of the water current, direction of the current, and the depth in the water column of the current. The ADCP would transmit frequencies at 35-1,200 kHz, also not expected to be within the hearing range of marbled murrelets. Some research has occurred for effects of ADCP instrument (sonar or "pingers") operations on seabirds. For example, Melvin et al. (1999) found that underwater acoustic pingers operating at 1.5 kHz (±1 kHz) at a signal duration of 300 ms (±10%) every 4 s (±10%) at 120 dB re 1 µPa deterred diving seabirds (common murre and rhinoceros auklet; family Alcidae) from gill nets used to catch salmon. When high-frequency sonar (greater than 10 kHz) is used, we expect that marbled murrelets can hear the sonar when the frequencies are between 10 and 11.5 kHz (Nelson 1997; Sanborn et al. 2005; SAIC 2012). Therefore, we do not anticipate marbled murrelets will be able to hear the sound produced by the ADCP, nor is the sound pressure level expected to result in significant behavioral changes (TS or TTS) near the source of the ADCP transmitter.

The effects of some of the other acoustic sources addressed above are expected to result injury ot behavioral impacts to individual marbled murrelets. However, since these effects will be taking place in the same area where airgun effects will occur, we anticipate little to no additional significant impacts to individual marbled murrelets are likely to occur beyond that discussed for the airguns.

<u>Other Possible Effects of Seismic Surveys</u>

Other possible effects of seismic surveys on marbled murrelets could include masking by vessel noise, disturbance by vessel presence or noise, and injury or mortality from collisions with vessels or entanglement in seismic gear. Vessel noise from R/V *Langseth* could affect marbled murrelets in the proposed survey area. The vessel will be traveling at a fairly slow speed of 4.1-4.2 knots (~6 mph) during seismic surveys. Houghton et al. (2015) proposed that vessel speed is the most important predictor of received noise levels, and Putland et al. (2017) also reported reduced sound levels with decreased vessel speed. Vessels have combustion engines which produce low-frequency, broadband underwater sound. Sounds produced by large vessels generally dominate ambient noise at frequencies from 20–300 Hz (Richardson et al. 1995). However, some energy is also produced at higher frequencies (Hermannsen et al. 2014). While the sound levels originating from operation of the vessels may be detectable by marbled murrelets, these sounds are transient and of a relatively short duration such that measurable effects are not anticipated. Therefore, effects of vessel noise on marbled murrelet are considered insignificant.

Summary of Key Findings of Effects of the Proposed Action on the Marbled murrelet

In the analyses presented above, the estimated areas of exposure encompass the full range of adverse effects, from temporary threshold shift to direct mortality. A very small number of individual marbled murrelets that are exposed to elevated sound pressure levels caused by the seismic surveys are likely to be killed or injured depending on their proximity to the source of these stressors. Possible injuries include loss in hearing sensitivity (TS), scarred or ruptured eardrums, or gastrointestinal tract lesions. Although affected marbled murrelets may survive their exposure to these and other stressors, they are likely to have a reduced level of fitness and reproductive success and have a higher risk of predation. Exposed individuals may also experience lethal injuries that occur instantaneously or over time, direct mortality, lung hemorrhaging, ruptured livers, hemorrhaged kidneys, ruptured air sacs, and/or coronary air embolisms.

Marbled murrelets that are expected to experience TS are expected to have damaged hair cells in their inner ears and, as a result, may not be able to detect biologically relevant sounds such as approaching predators or prey, and/or hear their mates or young attempting to communicate. Marbled murrelets that lose their hearing sensitivity are at increased risk of predation and reduced foraging efficiency. Some affected marbled murrelets may regain some or all of their hearing sensitivity; however, they are still temporarily at risk while experiencing TS.

Marbled murrelets that are expected to be exposed to other stressors caused by seismic surveys, but do not experience TS, are likely to experience interrupted foraging bouts or resting attempts, which creates a likelihood of injury by significantly disrupting normal behaviors (as a result of their diving repeatedly or vacating the area). Foraging efficiency is likely to be reduced, and energy expenditures are likely to be increased above normal when they flush and/or relocate out of the area. Marbled murrelets are also likely to increase their diving efforts in response to these lost foraging opportunities, or to replace prey dropped or swallowed, or to escape from perceived predator. Of the thousands of marbled murrelets potentially exposed, up to several hundred marbled murrelets are likely to be temporarily adversely affected in this manner across the entire survey area.

NSF established that the proposed action may expose thousands of marbled murrelets to injurious sound pressure levels based on marbled murrelet density and distance from the source. While the Service concludes some individual marbled murrelets will be exposed to injurious sound pressure levels, we have also determined that the actual number of marbled murrelets adversely impacted is likely to be low. We have reached this determination for the following reasons:

- Not all marbled murrelets upon which the density estimates are based are expected to be on the water at any given point in time during survey operations.

- Many marbled murrelets on the water may be loafing or resting instead of diving where they would be most likely affected by significant underwater sound pressure levels.
- Except during for a short period during pre-dawn and after sunset, marbled murrelets are not expected to be foraging during nighttime operations so will not be exposed to increased sound pressure levels during a significant period of the survey.
- Ocean conditions during the survey period are likely to promote marbled murrelet foraging activities closer to shore, likely resulting in fewer birds actually exposed to significant effects from increased sound pressure levels beyond 8 km from shore.
- The effect of increased sound pressure levels on marbled murrelet prey availability is expected to be short-term or insignificant limiting the risk of missed foraging attempts.
- Not all marbled murrelets actually exposed to increased sound pressure levels known to cause behavioral changes will experience temporary threshold shift or behavioral changes that result in a significant effect.

Cumulative Effects

Cumulative effects include the effects of future State, tribal, local or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA. The States of Oregon and Washington manage and authorize activities in territorial waters from the shoreline out to 3 nm from shore.

Many activities in State waters are managed by States, tribes, and local jurisdictions in a manner consistent with those in Federal waters (e.g., under fisheries management plans, and oil spill response plans). The USFWS, 2019 5-year status review for the marbled murrelet (2019, pg. 33-35) addressed threats related to the reduction of high-quality marbled murrelet food sources; that review is herein incorporated by reference. That review noted that Pacific herring and anchovy stocks may have been significantly reduced in part by overfishing, though little is known about these stocks due to limited sampling. Recreational fisheries are allowed, although rare, in marine waters. Until there is sufficient data available, Oregon is prohibiting development of new directed commercial harvest of forage fish, including the Pacific herring. In Washington and Oregon, there is no northern anchovy stock abundance information. However, there are commercial fisheries in State waters off the southern Washington coast, Grays Harbor, and Willapa Bay that provide live and packaged bait for recreational and commercial use. Since 2000, the highest reported landings of anchovy were in 2009 with over 800 metric tons being harvested; however, since 2010 the harvest levels have been below 300 metric tons. Pacific sardine fisheries have been closed more often than not in the recent past due to significant reduction in sardine biomass. While non-treaty sardine fisheries are closed, a small harvest amount was allocated to the Quinault Indian Nation that has conducted a commercial purse seine fishery within their usual and accustomed fishing grounds directly off Westport/Grays Harbor, Washington since 2012. Lesser quality marbled murrelet forage base includes surf smelt and sand lance. There continues to be no rigorous assessments of Washington's surf smelt stocks. Although there continues to be commercial and recreational fisheries for surf smelt in Washington, there are bycatch restrictions in place. We have no new information on the status of the sand lance in Washington. In Oregon, recreational fisheries are allowed, and sand lance may be incidentally taken during herring fishing, but the State has prohibited development of new directed commercial harvest of forage fish, including the Pacific sand lance.

Urbanization and residential development have led to the significant loss or physical alteration of intertidal and shoreline habitats, as well as to the contamination of many estuarine and nearshore areas (75 FR 63935; dated October 18, 2010). We are also incorporating by reference the analysis of cumulative effects prepared in the Programmatic Environmental Impact Statement/Overseas Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey (June 2011, section 4-1); that document includes a summary of cumulative effects affecting the marbled murrelet and its habitat within the action area, including fishing pressure, and other sources of underwater sound.

Conclusion

After reviewing the current status of the marbled murrelet, the environmental baseline for the action area, the effects of the proposed 2021 West Coast Seismic Survey and cumulative effects, it is the Service's biological opinion that the 2021 West Coast Seismic Survey, as proposed, is not likely to jeopardize the continued existence of the marbled murrelet. Therefore, the Service has concluded the level of take anticipated from the proposed NSF seismic survey is not likely to appreciably reduce the likelihood of its survival and recovery by reducing marbled murrelet numbers, reproduction, or distribution in the wild. We based this determination on the following factors:

- The effect of increased sound pressure levels on marbled murrelet prey availability is expected to be short-term or insignificant, and successful foraging bouts are likely to be only temporarily delayed, thereby posing limited risk of significant impacts resulting from missed foraging attempts.
- The presence of multiple onboard PSOs and associated protocols including shut down procedures is likely to avoid some risk of marbled murrelet exposure to increasing sound pressure levels in good visibility conditions.
- The vessels will have downward pointing lighting to limit the risk of significant injury to marbled murrelets due to vessel strikes.
- Due to the nature of the proposed action and the affected environment, we anticipate (1) a small number of marbled murrelets are likely to injured by increased sound pressure levels known to cause behavioral changes (threshold shift), and (2) relatively few marbled murrelets likely to be actively foraging in the areas where physical injury or mortality from increased sound pressure levels are expected because:
    - Marbled murrelets are not expected to be foraging during nighttime operations so will not be exposed to increased sound pressure levels during a significant period of the survey.
    - We anticipate stationary marbled murrelets will have substantial time to discern repetitive, increasing sound pressure levels coming toward them, and are likely to move away from oncoming survey vessels before sound pressure levels pose significant risk of injury.
    - The effects of the proposed action will be transitory in nature and dispersed across a wide area off the coast of Oregon and Washington, and in very few instances will the survey cover the same area more than once.
    - Ocean conditions during the survey period are likely to promote marbled murrelet foraging activities closer to shore, likely resulting in a low number of birds actually exposed to significant effects from increased sound pressure levels

beyond 8 km from shore.

Critical habitat for the marbled murrelet has been designated within terrestrial areas adjacent to the entirely marine-based 2012 West Coast Seismic Survey. However, the proposed action does is not likely to affect that area, therefore, no destruction or adverse modification of marbled murrelet critical habitat is anticipated as a result of implementing the proposed action.

INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined under section 3(19) of the ESA to mean "…harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Harm is further defined by the Service as an act which actually kills or injures wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering (50 CFR 17.3). Harass is defined by the ESA as an intentional or negligent act or omission that creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR 17.3). Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2) of the ESA, taking that is incidental to and not intended as part of the agency action is not considered to be a prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement (ITS).

The measures described below are non-discretionary and must be undertaken by the NSF for the exemption in section 7(o)(2) to apply. The NSF has a continuing duty to regulate the activity covered by this Incidental Take Statement. If the NSF (1) fails to assume and implement the terms and conditions or (2) fails to adhere to the terms and conditions of the incidental take statement, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the NSF must report the progress of the action and its impact on the species to the Service as specified in this Incidental Take Statement pursuant to the requirements of 50 CFR 402.14(i)(3).

Amount or Extent of Take

Based on the *Effects of the Action* analysis above, incidental take of the marbled murrelet is reasonably certain to occur in the form of harm. Pursuant to the authority of section 402.14(i)(1)(i) of the implementing regulations for section 7 of the ESA, a surrogate can be used to express the amount or extent of anticipated take if the following criteria are met: the causal link between the surrogate and take is described; an explanation is provided as to why it is not practical to express the amount or extent of take or to monitor take-related impacts in terms of individuals of the listed species; and a clear standard is set for determining when the level of anticipated take has been exceeded. The Service revised the ESA implementing regulations to clarify the use of surrogates to express the amount or extent of anticipated incidental take, including circumstances where project impacts to the surrogate are coextensive with at least one aspect of the project's scope (80 FR 26832, May 11, 2015). The Service supported this clarification of the ESA implementing regulations by noting that Congress has also recognized that a numerical value would not always be available and intended that such numbers be established only where possible [H.R. Rep. No. 97-

567, at 27 (1982)]. Also, noted in the above 2015 final rule, the preamble to the final rule that set forth the 1986 regulations also acknowledges that exact numerical limits on the amount of anticipated incidental take may be difficult to determine and the Services may instead specify the level of anticipated take in terms of the extent of the land or marine area that may be affected (51 FR 19926, June 3, 1986). The courts also have recognized that it is not always practicable to establish the precise number of individuals of the listed species that will be taken and that "surrogate" measures are acceptable to establish the impact of take on the species if there is a link between the surrogate and take (see Arizona Cattle Growers' Ass'n v. U.S. Fish and Wildlife Service, 273 F.3d 1229, 9th Cir. 2001). Furthermore, it is often more practical and meaningful to monitor project effects upon surrogates, which can also provide a clear standard for determining when the amount or extent of anticipated take has been exceeded and consultation should be reinitiated. Accordingly, a coextensive surrogate based on specific project components is necessary to express the extent of take because, based on the above analysis of effects, it is not practical to accurately estimate the actual number of marbled murrelets that may be incidentally taken or effectively monitor take impacts in terms of individual marbled murrelets due to the extremely low likelihood of finding dead or injured individuals in the aquatic environment. The coextensive surrogate is the direct source of the stressors causing the taking, and a clear standard for take exceedance can be established under the monitoring requirements (below) using this surrogate. On that basis, the extent of take of the marbled murrelet covered under this Incidental Take Statement is described using a coextensive surrogate: the proposed survey area in U.S. waters, survey length (6,306 km), total number of days (37), and placement of transects described in the proposed action description herein (Figures 1 and 2 herein).

As described in the effects analysis, we anticipate that the action will result in the incidental take in the form of harm within the proposed NSF seismic survey area. It is unlikely that all of these birds will be incidentally taken at the same location, rather the takings will be dispersed across the survey area. Based on the effects of the action analysis above, a very limited number of marbled murrelets are likely to be present in close proximity to the airgun arrays or survey vessels, exposed to significant sound pressure levels, and respond in a manner that conforms to take.

Effect of the Take

Based on the effects of the action analysis above, a very limited number of marbled murrelets are likely to be present in close proximity to the airgun arrays or survey vessels, exposed to significant sound pressure levels, and respond in a manner that conforms to take. In the accompanying Opinion, the Service determined that this level of anticipated take is not likely to result in jeopardy to the marbled murrelet.

Reasonable and Prudent Measures

The Service finds the following reasonable and prudent measures (RPMs) are necessary and appropriate to minimize the impacts of the taking on the marbled murrelet.

1. The NSF shall monitor the impacts of incidental take and report the progress of the action and its impact on the species.

2. The NSF shall implement required procedures to report, handle, or dispose of any individuals of an ESA-listed species actually taken.

Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the NSF must comply with the following terms and conditions, which implement the RPMs described above and outline required reporting/monitoring requirements. These terms and conditions are non-discretionary.

1. To implement RPM 1, the NSF shall implement the measures identified in the Proposed Monitoring and Reporting section herein. If any of the above monitoring requirements indicate the amount or extent of take has been exceeded, NSF shall discontinue the survey and immediately report this information to the Service. The Service requests NSF to provide the required report to the Assistant Regional Director, Ecological Services, U.S. Fish and Wildlife Service, 911 NE 11th Avenue, Portland, Oregon 97232.

2. To implement RPM 2, the NSF shall notify the Service within three working days upon locating any dead, injured, or sick endangered or threatened species specimens during project operations. Initial notification shall be made to the nearest U.S. Fish and Wildlife Service Law Enforcement Office (see below). Notification shall include the date, time and precise location (latitude/longitude); condition of the animal(s) (including carcass condition if the animal is dead); observed behaviors of the animal(s), if alive; if available, photographs or video footage of the animal(s); general circumstances under which the animal was discovered. Care should be taken in handling sick or injured specimens to preserve biological materials in the best possible state for later analysis of cause of death, if that occurs. In conjunction with the care of sick or injured endangered or threatened species or preservation of biological materials from a dead animal, the finder has the responsibility to ensure that evidence associated with the specimen is not unnecessarily disturbed. Contact information: the telephone number for the U.S. Fish and Wildlife Service Law Enforcement Office is (503) 682-6131, and for the Service's Columbia-Pacific Northwest Regional Office is (503) 702-5922.

The Service finds no more than the number or extent of species identified above will be incidentally taken as a result of the proposed action. The reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize the impact of incidental take that might otherwise result from the proposed action. If, during the course of the action, this level of incidental take is exceeded, such incidental take represents new information requiring reinitiation of consultation and review of the reasonable and prudent measures provided. The Federal agency must immediately provide an explanation of the causes of the taking and review with the Service the need for possible modification of the reasonable and prudent measures.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information.

The Service provides the following recommendations:

1. Please note that the Service is currently conducting a status review in response to a substantial listing petition for the tufted puffin (*Fratercula cirrhata*), which was also mentioned in your request for consultation. The puffin is listed as endangered by the State of Washington and could be present in the survey area during the survey period along with a number of migratory birds not listed under the ESA. We recommend the NSF apply the proposed conservation and mitigation measures identified in the Description of the Proposed Action section above to the tufted puffin.

2. As mentioned in the Effects of the Action section above, a bubble curtain concentrated around the air-gun ports could be an efficient and practical solution to reduce the high-frequency acoustic emission from air guns that may impact diving seabirds and other marine animals. The Service recommends that NSF consider use of bubble screens surrounding airgun arrays as a standard protocol to further reduce the low number of diving birds.

REINITIATION NOTICE

This biological opinion concludes formal consultation on the effects of the proposed action on the marbled murrelet. As provided in 50 CFR §402.16, reinitiation of consultation is required and shall be requested by the NSF or the Service, where discretionary Federal involvement or control over the action has been retained or is authorized by law and: (1) if the amount or extent of taking specified in the incidental take statement is exceeded; (2) if new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered in this biological opinion; (3) if the identified action is subsequently modified in a manner that causes an effect to listed species or critical habitat that was not considered in this biological opinion or concurrence determination; or (4) if a new species is listed or critical habitat designated that may be affected by the identified action.

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APPENDIX A

Analysis Supporting a "May Effect, but Not Likely to Adversely Affect" Determination for the Bull Trout and its Designated Critical Habitat

Bull Trout Status in the Action Area

The marine waters of Washington State provide important FMO habitat for anadromous subadult and adult bull trout. The action area overlaps marine habitat that provides important FMO habitat located outside of the three core areas of the Olympic Peninsula: Hoh River, Queets River, and Quinault River core areas.

Marine Habitat Use

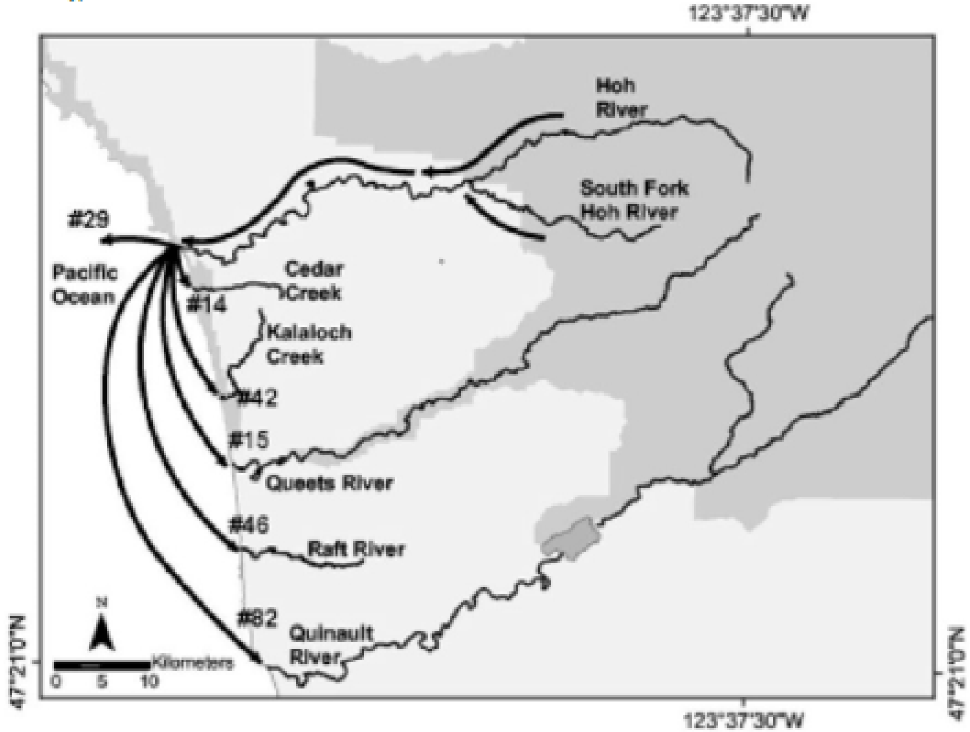
To understand exposure to effects of the action we must first reconcile that we understand very little about use of the outer coast marine environment by the bull trout. As such, effects of the action will be challenging to estimate. Studies conducted in the Hoh River have indicated between 57% and 85% of the fish exhibited anadromy at least once, and that 75% had migrated from fresh water to the sea multiple times (Brenkman and Corbett 2005, pg. 1075; Brenkman et al. 2007, pg. 1). Adjacent to the action area, other studies have demonstrated bull trout anadromy in Puget Sound (Hayes et al 2011, entire; Goetz et al. 2004, entire). These populations are thought to be found in marine habitats at any time of year (Hayes et al. 2011, pg. 403; Goetz et al. 2016, pg. 103).

The nearby Skagit River, Washington, has been identified as one of the more robust populations of bull trout in the Coastal RU, where Hayes et al. (2011, pg. 402) demonstrated extent of marine habitat use by individual bull trout for up to 133 days. In this study, 60% of the river tagged bull trout moved into Skagit Bay from March until May and were back in the river from May to August. Other studies showed marine habitat use from April until July in the Puget Sound (Goetz et al. 2004, entire; 2007, pg. 8; 2016, pg. 90). Goetz (2016, pg. 104) found this timing of the bull trout return to streams was synchronous in several rivers despite differences in thermal regimes, and noted this is typical of partial migration patterns of other iteroparous species that do not typically use marine waters over winter.

However, subadult bull trout from the Hoh River were detected in the Pacific Ocean between September and December (Brenkman et al. 2007, pg. 5). In another study, bull trout migrated down from the Snohomish River in November entered into the Duwamish River in December and returned to the Snohomish River in January (Goetz 2012, pg. 10) demonstrating bull trout are in the marine waters after spawning. Fish were detected moving between rivers in Puget Sound rather than residing there, during the fall and winter period, similar to behaviors seen in Pacific Ocean bull trout (Goetz 2016, pg. 104; Brenkman and Corbett 2005, pg. 2). In 2003, sub-adult and adult bull trout were observed in the Skagit River delta and bay in late fall and winter (Goetz 2016, pg. 104). A total of 39 of 73 tagged bull trout in the Hoh River basin moved into the ocean during various months (Brenkman and Corbett 2005, pg. 1075); and some fish were detected later in coastal streams located between 5 and 47 km to the south of the Hoh River. This includes Cedar Creek, Kalaloch Creek, the Queets River, the Raft River, and the Quinault River (Figure 1). One recent survey (Smith and Huff 2019, pg. 3) further demonstrated bull trout use of marine habitats in the action area, where from May to September 2019, movements of six bull trout were monitored after being tagged in the Hoh River, and 11 in Kalaloch Creek. However, in this study only one tagged bull trout was detected (in August) in marine habitat. This variation of the data in these studies could be due in part to differences in survey method but is also likely attributed to habitat or behavioral differences between populations. For instance, Skagit fish were tagged in the lower river (Hayes et al. 2011, pg. 403), while Hoh River fish in one study were tagged in the lower and upper river (Brenkman et al. 2007, pg. 3). Nevertheless, the data seems to indicate bull trout use of the nearshore marine environment is variable and may be extensive. It is reasonable to assume adult spawning fish would return to the natal rivers to spawn, while juveniles, smaller sub-adults, and the occasional non-breeding adult may remain in the marine environment.

Several of these studies have shown bull trout travel distances upwards of 60 km (Hayes et al 2001, pg. 403; Brenkman and Corbett 2005, pg. 1075; Goetz et al. 2004, pg. 44) and one study demonstrated a minimum travel distance of 100-160 km (Goetz et al. 2004, pg. 44). Bull trout tagged in previous years have also been shown to make multiple migrations into marine habitats (Brenkman et al. 2007, pg. 5). Brenkman and Corbett (2005, pg. 1078) demonstrated typical movement in the action area in Figure 1.

Figure 1. From Brenkman and Corbett (2005, pg. 1078). Downstream movements of anadromous bull trout from the Hoh River basin to the Pacific Ocean and nearby coastal drainages.



Adult and subadult bull trout may primarily use that surf zone area of the action area at any time of year. However, an estimate of the number of bull trout that use marine waters to forage, migrate, and overwinter in the action area is not available, and limited abundance data is available for bull trout use of rivers adjacent to these marine habitat areas (see Table 1). The Service expects that low numbers of bull trout are likely to forage, migrate, and overwinter in the surf zone area of the action area, and it is possible bull trout may forage further offshore.

Table 1. Olympic Peninsula geographic region, outer coastal core area local population adult abundance size estimates, short-term trend, and ranking for risk of extirpation (USFWS 2015a, entire; 2008 entire).

Core Area	Population Abundance – Individuals	Short-Term Abundance Trend	Final Ranking for Risk of Extirpation
Hoh River	250-1000	Increasing	At Risk
Queets River	Unknown	Unknown	Potential Risk
Quinault River	Unknown	Unknown	At Risk

Threats and Conservation Needs

The Coastal Recovery Unit Implementation Plan for the bull trout suggests core areas along the Pacific Coast of Washington likely have the best demographic status in the Olympic Peninsula region (USFWS 2015a, pg. A-7). Although abundance and trends are unknown for the Quinault River core area, it was identified as the one stronghold in this region (FWS 2015, p. A-3). However, direct and incidental catch of bull trout from commercial gill net and popular recreational angling fisheries on the coast can have significant selective pressure on older and larger bull trout. Incidental catch has been amplified by regional salmon and steelhead ESA listings that have shifted regional recreational angling effort to coastal streams; and has been demonstrated to be significant in some Tribal fisheries (USFWS 2015a, pg. A-18). Development and implementation of strategies to reduce incidental mortality of larger spawners caught in fisheries is needed to conserve core area populations along the Pacific Coast. To resolve the lack of data regarding population numbers and FMO habitat use, overwintering index areas should be established.

Although these small independent streams along the Pacific Coast have been identified as either medium or low priority watersheds for salmon compared to larger natal watersheds, these are key shared FMO habitats for anadromous bull trout (USFWS 2015a, pg. 71). Many of these small streams whose estuaries and lower reaches are used by anadromous bull trout have been heavily impacted by past forest practices. Associated impacts cause degradation to a number of small, nonnatal, independent Pacific Coast streams and their estuaries that are essential for overwintering and foraging by the anadromous life history form (USFWS 2015a, pg. A-21). Improved roads paralleling the coastal rivers continue to impact habitat within stream corridors through loss of riparian areas, bank stability efforts, channel simplification of FMO habitat, and altered tributary connectivity (USFWS 2015a, pg. A-18). Recovery implementation goals include appropriate protection and restoration actions and identifies numerous partners in this effort (USFWS 2015a, pg. 116).

The Service has consulted with the Navy on a number of actions related to training, operations, and facilities maintenance, including pile driving, sonar and underwater explosions in the action area. We completed consultations with the Army Corps of Engineers on a number of boat ramp, bulkhead, and riprap installation projects that resulted in temporary and permanent shoreline habitat modification. We have completed consultations with NMSF on salmon, halibut and groundfish fisheries management plans that may result in bycatch of the bull trout.

Bull Trout Critical Habitat Status in the Action Area

In marine nearshore areas, the inshore extent of critical habitat is the mean higher high-water (MHHW) line, including the uppermost reach of the saltwater wedge within tidally influenced, freshwater heads of estuaries. Critical habitat extends offshore to the depth of 10 meters (m) (33 feet (ft)) relative to the mean low low-water (MLLW) line (USFWS 2010, pg. 63935). The quality of marine habitat along shorelines is intrinsically related to the character of adjacent features, and human activities that occur outside of the MHHW line and can have major effects on the physical and biological features of the marine environment. The offshore extent of critical habitat for marine nearshore areas is based on the extent of the photic zone, which is the layer of water in which organisms are exposed to light (USFWS 2010, pg. 63973). This area between the MHHW line and minus 10 m MLLW line is considered the habitat most consistently used by bull trout in marine waters based on known use, forage fish availability, and ongoing migration studies and captures geological and ecological processes important to maintaining these habitats.

The action area includes designated bull trout critical habitat from Unit 1 (Olympic Peninsula). With our revised designation of bull trout critical habitat (75 FR 63935; October 18, 2010) the USFWS identified a number of marine and mainstem river habitats outside of bull trout core areas that provide the PCEs of critical habitat. These areas do not provide spawning and rearing habitat but do provide FMO habitat that is typically shared by bull trout originating from multiple core areas. These shared FMO areas support the viability of bull trout populations by contributing to successful overwintering survival and dispersal among core areas (USFWS 2015, pg. 35).

There is widespread agreement in the scientific literature that many factors (mostly related to human activities) have impacted bull trout and their habitat and continue to do so. Among the many factors that individually and cumulatively degrade the current function of the PCEs of designated bull trout critical habitat, those that appear to be particularly significant and have resulted in a legacy of degraded habitat conditions are as follows.

Fragmentation and isolation of local populations due to the proliferation of dams and water diversions that have eliminated habitat, altered water flow and temperature regimes, and impeded migratory movements (Dunham and Rieman 1999, pg. 652; Rieman and McIntyre 1993, pg.7).
Degradation of spawning and rearing habitat in upper watershed areas, particularly alterations in sedimentation rates and water temperature, resulting from forest and rangeland practices and intensive development of roads (Fraley and Shepard 1989, pg. 141; The Montana Bull Trout Scientific Group 1998, pp. ii-v, 20-45).
The introduction and spread of nonnative fish species, particularly brook trout (*S. fontinalis*) and lake trout (*S. namaycush*), as a result of fish stocking and degraded habitat conditions, which compete with bull trout for limited resources and, in the case of brook trout, hybridize with bull trout (Leary et al. 1993, pg. 857; Rieman et al. 2006, pg. 73).
Degradation of mainstem river FMO habitat, and the degradation and loss of marine nearshore FMO habitat due to urban and residential development.
Degradation of FMO habitat resulting from reduced prey base, roads, agriculture, development, and dams.

The final rule designating bull trout critical habitat identified nine Primary Constituent Elements (PCEs) essential for the conservation of bull trout. Five of the nine PCEs are found in the marine waters of the action area:

PCE 2. Migratory habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers. Within the action area, migratory habitat functions are variable. Conditions range between mostly intact and undisturbed, and substantially disturbed and impaired. The current condition and function of this PCE in the action area may be described generically as moderately impaired.

PCE 3. An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish. Within the action area, food base functions are variable. Conditions range between mostly intact and undisturbed, and substantially disturbed and impaired. The current condition and function of this PCE in the action area may be described generically as moderately impaired.

PCE 4. Complex river, stream, lake, reservoir, and marine shoreline aquatic environments and processes with features such as large wood, side channels, pools, undercut banks and substrates, to provide a variety of depths, gradients, velocities, and structure. Within the action area, shoreline environments, processes, and functions are variable. Conditions range between mostly intact and undisturbed, and substantially disturbed and impaired. The current condition and function of this PCE in the action area may be described generically as moderately impaired.

PCE 5. Water temperatures ranging from 2 °C to 15 °C (36 °F to 59 °F), with adequate thermal refugia available for temperatures at the upper end of this range. Specific temperatures within this range will vary depending on bull trout life-history stage and form; geography; elevation; diurnal and seasonal variation; shade, such as that provided by riparian habitat; and local groundwater influence. Within the action area, water temperatures and thermal refugia functions are variable. Conditions range between mostly intact and undisturbed, and substantially disturbed and impaired. The current condition and function of this PCE in the action area may be described generically as moderately impaired.

PCE 8. Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited. Within the action area, conditions range between mostly intact and undisturbed, and substantially disturbed and impaired. The current condition and function of this PCE in the action area may be described generically as moderately impaired.

Effects of the Action on the Bull Trout

The proposed action involves exposure to underwater sound (repeated explosions) in waters deeper than 200 m, but that will likely esonify up to the shoreline. We demonstrated in the Environmental Baseline section bull trout use of marine habitats, to understand level of exposure it is important to estimate bull trout behavior at sea. While most studies have indicated bull trout more commonly stay near the shoreline, a single bull trout tagged in Kalaloch Creek, WA, was detected multiple times on August 25, 2019, at a location 5.6 nautical miles from shore between the Queets River and Quinault River (Smith and Huff 2020, pg. 3). Another exceptional

Snohomish River fish on a 95 km one-way journey, crossed Puget Sound twice (minimum distance 6.5 km) (Goetz 2012 et al., pg. 12). In the Skagit study, most fish were detected within 400 m of the shoreline and in waters less than 4 m (Hayes et al. 2011, pg. 403). Goetz et al. (2004, pg. 58) similarly showed bull trout densities were greatest at depths between 2–5 m. It is reasonable to assume most adult spawners will be in the streams adjacent to the action area during the proposed action timeframe, while an unknown number of adults, sub-adults and juveniles may use marine waters at any time of the year.

In the NSF-updated project description, track lines were modified adjacent to the Washington coast such that the tracklines will come no closer than 21 km (11 nm) from shore, in waters greater than 100 m depth, the exposure risk is minimized for bull trout from proposed action consequences. According to the NSF, the ensonified area (the Level B 160dB zone) would also remain outside of the 100 m isobaths. Most of the fish in the action area are likely to be from the three coastal core areas in Washington: Hoh, Queets, and Quinault Rivers. Based on prior status reviews (USFWS 2008, entire; 2015, entire), it is estimated approximately 250-1000 bull trout may occur in the Hoh River, and while population numbers were thought to be increasing at that time, in the long term, given the small population size, the Hoh River core area was also considered at risk of extirpation. There are no population estimates for the Queets and Quinault Rivers, but these drainages were identified by the Service as "potentially at risk" and "at risk" respectively (USFWS 2008, entire; 2015, entire). Lower population numbers may be depressed by slow growth and reproduction rates, and susceptibility to overharvest in recreational fisheries (Brenkman and Corbett 2005, pg. 1080; Post et al. 2003, pg. 31), suggesting additional mortality from the proposed action, even to a small number of fish, may be significant to the affected populations.

The shallow nature of the underwater explosions is unlikely to result in elevated water at the shoreline, a result usually attributable to deep underwater explosions.

<u>Consequences of Exposure</u>

An explosive or pile-driving sound wave is very broad and fast-moving, and produces a supersonic shock wave known to cause barotrauma in animals. The escape of air from an airgun is very slow compared to a pile driving or explosive source, so unlike pile driving or explosives, there is no shock wave from an airgun so no resulting barotraumatic effect that would cause fish mortality (Gisiner 2019, entire). Furthermore, the sound gets less "peaky" as it travels at distance, bounces off the bottom, and is refracted as it travels through water, so the sound tends to spread out resulting in pink noise (not white noise) with a lot of amplitude modulation, and eventually there is no peak with distance (Gisiner 2019, entire). Airguns do not mask signals well so animals can still hear each other between peaks and valleys of sound. The barotraumas injuries associated with exposure to high sound pressure levels include hemorrhage and rupture of internal organs, hemorrhaged eyes, and temporary stunning (Yelverton et al. 1973, p. 37; Yelverton et al. 1975, p. 17; Yelverton and Richmond 1981, p. 6; Turnpenny and Nedwell 1994; Hastings and Popper 2005). Death from barotrauma can be instantaneous, occurring within minutes after exposure, or several days later (Abbott et al. 2002). While underwater airguns are similar to pile-driving in that both exhibit full spectrum sound and both have the potential to cause harmful behavioral or physiological responses by exposed animals, the slow release of compressed air is far less likely to cause injury and mortality in fishes that has been attributed to impact pile driving (Stotz and Colby 2001; John H. Stadler, NMFS, pers. comm. 2002; Fordjour 2003; Abbott et al. 2005; Hastings and Popper 2005).

Several studies have confirmed an effect on fish behavior from sounds from compressed air sources used for seismic exploration. Research has shown catch rates of commercial fish species including cod and haddock declined in areas where airguns were used, and increased 30-50 km away from the sound source, signaling that these fishes avoided the areas where the compressed seismic sources were operating (Slotte et al 2004, entire; Engås et al. 1996, entire). However, other research indicates the reverse response, with more fish being caught in gill nets near areas where compressed air sources were being used for seismic exploration (Løkkeborg et al 2012, entire). In another study, rockfishes exhibited behavioral changes from underwater geophysical surveys at 161 dB and at 180 dB swam in tight circles or moved to the seafloor (Pearson et al 1992, entire).

In other research, no biologically significant effect was found to result from airguns on fish behavior. In one study using coral reef fishes in contained enclosures, swimming speed and increased and swimming direction changed (196 dBpeak at 1 m) but returned to normal soon after (Boeger et al. 2006, entire). Furthermore, repeated exposure to sounds generated by compressed air sources reduced these responses, suggesting habituation to the disturbance may have occurred. In other research, pollack and juvenile saithe in nearshore habitat did not indicate a significant behavioral response to sound from airguns. Fishes were initially startled but remained in position on the reef and their diurnal gatherings on the reef were not affected by sound exposure of 210 dBpeak at 16 m from the source, and 195 dBpeak at109 m (Finneran et al. 2015, entire). However, at 5 m and 218 dBpeak fish did react by moving away.

Given the large amount of uncertainty, however, that lies not only in extrapolating from experimental data to the field, but also between sound sources (compressed air vs. pile driving), and also from one species to another, we believe it is appropriate to utilize the most conservative known level for anticipating behavioral responses. As such, we expect that sound pressure levels in excess of 150 dBrms will cause temporary behavioral changes in bull trout. They are not expected to cause injury. We expect that sound pressure levels above 150 dBrms could result in a temporary alteration of normal foraging and migrating behavior in bull trout. Should sound pressure levels lead to bull trout avoiding an area, or altering their migration timing, it could represent a significant disruption in foraging and migratory behavior. Whether these behavioral effects result in "adverse effects" depend on a number of additional factors such as the duration and timing of exposure, species life histories, and the species' normal use of the area during exposure.

In assessing impacts to marine mammals, NSF determined for the proposed project the distance from the source of ensonification that it takes to attenuate below 160 dBrms is 12.5 km in waters less than 100m and 9.5 km in waters between 100 and 1000m and is 6.7 km in waters greater than 1000m deep. Off the coast of Washington, the tracklines have been pushed offshore (>21 km; 11 nm). Based on this information, we can expect the sound will attenuate to below 150 dBrms (the behavioral response threshold measured at 1 µPa (rms)) somewhere below the 100m depth contour, but still well outside of the likely shallow, nearshore, habitat use area for most bull trout resulting in limited insignificant behavioral responses from the very small number of fish that may be present in deeper water.

For salmon, NMFS is using 186 SEL for TTS (temporary threshold shifts) and 207 SPLpeak for onset of injury for the proposed action. NSF, based on a ship speed of 4.1-4.2 kts and a shot interval of 37.5 m, determined the radius around the vessel at which animals could be exposed to sound levels up to 202 dB SEL was estimated to be 84 m. NMFS calculated a distance to 203 dB SELcum of 4,024.4 m (4 km). This information is based on calculations for SELcum and SELpeak and NMFS chose the greater distance between the two. While it is unclear why there is such a large difference between NMFS and NSF calculations, it is reasonable, due to similar taxonomic and life history characteristics, that we should extrapolate this salmon exposure information for the bull trout. However, given very limited data supporting a likelihood that individual bull trout forage in waters this far offshore, we do not have strong evidence that bull trout are likely to be exposed to injurious effects coincidental with the proposed action at this distance (>17 km, 9 nm). Therefore, is extremely unlikely that individual bull trout will be physically injured as a result of the proposed action.

The proposed use of surface ships, sonar, or other acoustic devices will also result in increased noise levels that could extend into bull trout foraging, migration, and overwintering areas along the outer coast of Washington. This risk is mitigated somewhat by the vessel will be operating in and out of its home port of Newport, Oregon. In addition, these increased sound levels are intermittent or are at frequencies that are not expected to impede bull trout foraging or migratory behavior. Therefore, effects associated with these project elements are considered insignificant.

Effects of the Action on Bull Trout Critical Habitat

As stated in the "Status of the Bull Trout" section above, only PCEs 2, 3, 4, 5, and 8 apply to marine nearshore waters identified as critical habitat. The proposed activities will have no effect on PCEs 4, 5, and 8. The activities will not result in any permanent changes or alterations to marine shoreline habitat, impact water temperatures or water quality in the designated critical habitat area. The activities may affect the following PCEs:

PCE 2 and PCE 3: Activities conducted in waters adjacent to CHU 1 include the use of sonar and airguns that result in increased sound pressure levels that can temporarily act as an impediment within the marine migratory and corridor and primary nearshore foraging areas. However, the area in which potential migratory and foraging bull trout behavioral responses to sound or sound pressure is well away from the source, and therefore the migratory corridor and foraging areas, including bull trout prey species, will not be significantly impeded. Based on the species analysis above, we can expect the sound will attenuate to below 150 dBrms (the behavioral response threshold measured at 1 µPa (rms)) somewhere below the 100m depth contour, but still well outside of the likely shallow, nearshore, migratory and foraging critical habitat use area for bull trout resulting in no significant behavioral responses from fish that may be present. The proposed use of surface ships, sonar, or other acoustic devices will also result in increased noise levels that could extend into designated critical habitat. However, these increased sound levels are intermittent or are at frequencies that are not expected to impede bull trout migration or foraging behavior or success, since we do not expect these impacts to result in a long-term reduction in forage fish abundance. Therefore, the proposed action is not expected to significantly degrade the function of critical habitat.

Conclusion

Based on the NSF BA, the proposed action description, taken together with the above analysis, it is the Service's determination that the proposed action may affect but is not likely to adversely affect the bull trout or its critical habitat.

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APPENDIX G: COASTAL ZONE MANAGEMENT ACT COMPLIANCE

Appendix G: Coastal Zone Management Act Compliance

From: "Caracciolo, Deanna" <deanna.caracciolo@state.or.us>
Date: Wednesday, March 4, 2020 at 4:00 PM
To: "Smith, Holly E." <hesmith@nsf.gov>
Subject: [EXTERNAL] - NSF 2020 Geophysical Survey Action - Federal Consistency Presumed

> This email originated from outside of the National Science Foundation. Do not click links or open attachments unless you recognize the sender and know the content is safe.

Greetings Holly,

Today is the decision deadline for the Oregon federal consistency decision pertaining to the proposed Marine Geophysical Survey of the Cascadia Subduction Zone. At this time, please presume state concurrence for the proposed action.

Please don't hesitate to reach out with any questions regarding this presumed concurrence.
Regards,
Deanna

DLCD

Deanna Caracciolo
State-Federal Relations Coordinator | Oregon Coastal Management Program
Oregon Department of Land Conservation and Development
635 Capitol Street NE, Suite 150 | Salem, OR 97301-2540
Direct: 503-934-0026 | Cell: 503-956-8163 | Main: 503-373-0050
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STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
PO Box 47600 • Olympia, WA 98504-7600 • 360-407-6000
711 for Washington Relay Service • Persons with a speech disability can call 877-833-6341

March 23, 2020

National Science Foundation
Attn: Holly Smith
2415 Eisenhower AVE
Alexandria VA 22314-4684

RE: Coastal Zone Consistency Decision for Activities Undertaken by a Federal Agency
Marine Geophysical Survey of the Cascadia Subduction Zone
Northeastern Pacific Ocean, offshore Washington and Oregon States

Dear Holly Smith:

On January 8, 2020, the National Science Foundation (NSF) submitted a Consistency Determination to the Washington Department of Ecology - manager of the State's Coastal Zone Management Program (CZMP). As described in the Consistency Determination, the NSF proposes to conduct a high-energy marine geophysical survey in late spring/summer 2020 within the Exclusive Economic Zone of the U.S. The NSF is funding the proposal, and it is led by principal investigators from multiple academic institutions and the United States Geological Survey (USGS). The overarching goal of the study is to use modern multi-channel seismic data to characterize subducting plate and accretionary wedge structure, and properties of the megathrust, along nearly the full length of the Cascadia Subduction Zone.

Pursuant to Section 307(c)(3) of the Coastal Zone Management Act of 1972 as amended, Ecology concurs with NSF's determination that the proposed work is consistent with Washington's CZMP. The NSF demonstrated that its proposal is consistent with the CZMP's enforceable policies found in Washington's Ocean Resource's Management Act and the Ocean Management Guidelines, which call for no long-term significant impacts to Washington's coastal zone resources or uses. WAC 173-26-360(7)(j): states *"Ocean uses and their associated coastal or upland facilities should be located, designed and operated* ***to prevent, avoid, and minimize adverse impacts on migration routes and habitat areas of species listed as endangered or threatened****, environmentally critical and sensitive habitats such as breeding, spawning, nursery, foraging areas…".*

NSF Coastal Zone Consistency Decision
Page 2 of 2

While we acknowledge that the NSF proposal meets the above enforceable policies to the maximum extent practicable, we must also recognize that Washington's Southern Resident Killer Whales, which are an endangered species, are under particular threat. Thus, in order to emphasize our concern and need to ensure that the population will not be subjected to additional stress, we are recommending measures that we believe will further ensure protection for these marine mammals. These recommendations are the result of consulting with NMFS as called for by the CZMA, and also with Washington's Department of Fish and Wildlife who has oversight authority for Killer Whale populations that feed and transit through Washington State waters.

We appreciate your willingness to work closely with us and provide information as needed, prior to and after receiving your proposal. We believe that communication between state and federal agencies, when working on projects under the Coastal Zone Management Act, enhances our ability to protect the nation's and state's precious coastal resources.

Should you have questions or concerns, please do not hesitate to contact Therese Swanson at 360 407-6789 or terry.swanson@ecy.wa.gov.

Sincerely,

Brenden McFarland, Section Manager
Environmental Transportation and Review Section
Shorelands and Environmental Assistance Program

Enclosure

E-CC: Jennifer Hennessey, Office of the Governor – Jennifer.Hennessey@gov.wa.gov
Jessica Stocking, WDFW – Jessica.stocking@dfw.gov
Wendy Largent, Hoh Tribe - Wendy.Largent@hohtribe-nsn.org
Ervin (Joe) Schumacker, Quinault Tribe - JSCHUMACKER@quinault.org
Katie Wrubel, Makah Tribe - Katie.wrubel@makah.com
Chad Bowechop, Makah Tribe - chad.bowechop@makah.com
Jennifer Hagen, Quileute Tribe - jennifer.hagen@quileutetribe.com
Amy Fowler, NMFS – amy.fowler@noaa.gov
Colette Cairns, NMFS – collette.cairns@noaa.gov
George Galasso, OCNMS – George.galasso@noaa.gov
ECYFEDPERMITS@ecy.wa.gov
Therese Swanson, Ecology – terry.swanson@ecy.wa.gov

Washington Coastal Zone Management Program Recommendations for Protection of Marine Mammals, particularly Southern Resident Killer Whales during the Marine Geophysical Survey off the Cascadia Subduction Zone
March 23, 2020

Washington is very concerned about its Southern Resident Killer Whale population and is making the following recommendations to consider when conducting the seismic surveys:

The current population estimate for Southern Residents is at 73 individuals. Approximately 59 percent of the total population is predicted to be exposed to effects from the seismic survey activities, which could disrupt the animals' feeding, inhibit the pods' ability to communicate during foraging, and impact prey species. These effects could undermine the animals' health and fitness. Thus, we are recommending mitigation measures aimed at eliminating or reducing the exposure of the Southern Resident Killer Whales. We recommend a closure area within the action area for the survey, and have consulted with NMFS on measures that it is proposing.

The area with the highest likelihood of Southern Resident killer whale occurrence should be closed to surveys, from just south of the Columbia River, north to approximately off Cape Flattery (exclusive of the territorial seas of Canada), and seaward to 200 meters depth. Additionally, we recommend the following Southern Resident Killer Whale specific detection-based mitigation measures:

- The airgun array must be shut down upon visual observation or acoustic detection of a killer whale at ANY distance;
- Tracklines in waters 200 m deep or less must be surveyed in daylight hours only (from 30 minutes before sunrise to 30 minutes after sunset);
- When surveying in waters 200 m deep or less, a second vessel (with two protected-species observers on duty at all times) must travel along the trackline ahead of the Langseth and relay sightings of marine mammals to observers on the Langseth to prepare for shutdowns.

Some general mitigation measures for other marine mammal species include:

- Implementing a 500-m exclusion zone, meaning the airgun array must be shut down when animals come within 500 m of the array. There is an exception to this shutdown requirement for certain genera of dolphins (Tursiops, Delphinus, Stenella, Lagenorhynchus, and Lissodelphis) that are known to approach vessels and are relatively insensitive to sound produced at the predominant frequencies in an airgun pulse while also having a relatively high threshold for the onset of auditory injury (i.e., permanent threshold shift);
- Shutting down the airgun array when groups of six or more large whales (sperm and baleen) are observed together, or a large whale **with a calf** are observed at any distance from the array;
- Using passive acoustic monitoring during **all** survey operations;
- Gradually ramping up the airgun array from a single airgun to the whole active array;
- Implementing vessel strike avoidance measures.

APPENDIX H: OCNMS SRS & PERMIT

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE
OFFICE OF NATIONAL MARINE SANCTUARIES
Olympic Coast National Marine Sanctuary
115 East Railroad Avenue, Suite 301
Port Angeles, WA 98362-2925

March 12, 2021

Amy Fowler
Incidental Take Program
National Marine Fisheries Service Office of Protected Resources
1315 East-West Highway
Silver Spring, MD 20910

Holly Smith
National Science Foundation
2415 Eisenhower Avenue
Alexandria, Virginia 22314

Dear Ms. Fowler and Ms. Smith:

On May 1, 2020, the National Oceanic and Atmospheric Administration (NOAA) Office of National Marine Sanctuaries (ONMS) received the National Science Foundation (NSF) and NOAA National Marine Fisheries Service (NMFS) initial Sanctuary Resource Statement (SRS) and request to initiate consultation under the National Marine Sanctuaries Act (NMSA; 16 U.S.C. § 1434) for a proposed marine geophysical survey of the Cascadia Subduction Zone in the northeast Pacific Ocean using the R/V *Marcus G. Langseth*. The proposed action includes the issuance of an incidental harassment authorization under the Marine Mammal Protection Act (MMPA) by NMFS to Lamont-Doherty Earth Observatory for takes of marine mammals incidental to the geophysical surveys (April 7, 2020; 85 FR 19580). The SRS references the permit application to Olympic Coast National Marine Sanctuary (OCNMS) initially submitted on December 17, 2019 and a Draft Environmental Assessment prepared by NSF (dated November 21, 2019). After ONMS's request for additional information and clarification, ONMS received a revised permit application on May 15, 2020 and a revised SRS on January 22, 2021. On January 27, 2021, ONMS found the SRS sufficient for the purposes of making an injury determination and developing recommended alternatives as required by the NMSA.

Pursuant to section 304(d) of the NMSA, we hereby provide ONMS's injury determination and recommended alternatives to minimize injury and to protect sanctuary resources. ONMS finds that proposed NSF activities within and outside of the sanctuary will result in injury in the form of harassment of marine mammals in the sanctuary. ONMS provides two recommended alternatives to minimize injury and to protect sanctuary resources:

I. Limit operations in OCNMS to daylight hours only regardless of depth; and
II. Use of the secondary support vessel aiding in marine mammal observations throughout the entire sanctuary.

The enclosed document provides additional information and analysis supporting this injury determination and recommended alternatives.

Consistent with section 304(d)(3) of the NMSA, once NSF and NMFS have had an opportunity to consider our recommended alternatives, please engage ONMS for further consultation on these alternatives. Should NSF and NMFS decide not to follow our alternatives (as provided herein or modified in further consultation), please provide ONMS with a written statement documenting your decision and rationale. Finally, pursuant to section 304(d)(4) of the NMSA, if NSF and NMFS takes an action other than those recommended herein, and such action results in injury to a sanctuary resource, the heads of NSF and NMFS are required to promptly prevent and mitigate further damage, and restore or replace the sanctuary resources in a manner approved by ONMS.

This consultation applies to the proposed action as defined in NSF's draft Environmental Assessment and NMFS's proposed authorization of take. NSF and NMFS must reinitiate consultation with ONMS if either agency determines that they trigger the NMSA's consultation requirements. Specifically:

- If the action is modified such that it is likely to destroy, cause the loss of, or injure a sanctuary resource or quality in a manner different or greater than was considered in a previous consultation under section 304(d) of the NMSA; or
- If the action is likely to destroy, cause the loss of, or injure any sanctuary resource or quality not considered in a previous consultation under 304(d); or
- If new information reveals that the action it is likely to destroy, cause the loss of, or injure a sanctuary resource or quality in a manner different or greater than considered in a previous consultation; or
- If a new action is proposed that is likely to destroy, cause the loss of, or injure a sanctuary resource.

Please contact me at carol.bernthal@noaa.gov, or 360-406-2075, with any questions you may have on these recommended alternatives. We look forward to continuing to work with you and your staff to meet NSF's and NMFS's mission objectives and to protect the Nation's national marine sanctuaries.

Respectfully,

Carol Bernthal

Carol Bernthal, Superintendent
Olympic Coast National Marine Sanctuary

Enclosure:

cc: Timothy J. Greene, Chairman, Makah Tribal Council
JoDean Haupt-Richards, Secretary, Makah Tribe
Russell Svec, Director, Makah Fisheries Management, Makah Tribe
Haley Kennard, Environmental Policy Analyst, Makah Tribe
Ed Johnstone, Fisheries Policy, Quinault Indian Nation
Joe Schumacker, Marine Scientist, Quinault Indian Nation
Frank Geyer, Director, Quileute Natural Resources, Quileute Tribe
Jennifer Hagen, Marine Policy Advisor, Quileute Tribe
Wendy Largent, Natural Resources Director, Hoh Tribe
Julie Ann Koehlinger, Timber, Fish, and Wildlife Biologist, Hoh Tribe

ONMS Injury Determination and Recommended Alternatives for Consultation under the National Marine Sanctuaries Act for the 2021 National Science Foundation Activities

March 12, 2021

I. Background

The proposed federal agency actions subject to consultation consist of the National Science Foundation's (NSF) 2021 high-energy seismic surveys using a 36-airgun array and deployment of Ocean Bottom Seismometers, and NMFS's proposed issuance of an incidental harassment authorization (IHA) for take of marine mammals incidental to these activities. The area of the geophysical survey and proposed impacts overlaps with OCNMS. In the SRS, NMFS and NSF find that the proposed action may incidentally expose marine resources within OCNMS to sound and other environmental stressors associated with seismic surveys. This consultation considers activities occurring both within and outside the sanctuary's boundaries that are likely to injure sanctuary resources.

NSF activities within the scope of this consultation

As described in Section 1 of the SRS and in Section 2.1.2.1 of NSF's draft EA, NSF's proposed action is seismic survey (SRS; dated January 22, 2021). The scope of this consultation is focused on the proposed track lines for seismic airguns (36-airgun array) and temporary deployment of three ocean bottom seismometers (OBSs) within OCNMS. In Section 4 of the 2021 SRS, NSF concludes that activities are only likely to directly injure sanctuary resources through exposure to sound and energy for which an incidental harassment authorization has been requested. See Table 3 of the SRS for further information. The National Marine Fisheries Service proposes to issue a Marine Mammal Protection Act (MMPA) incidental harassment authorization (IHA) to Lamont-Doherty Earth Observatory (L-DEO) for take, by Level A and Level B harassment, of individuals of several species of marine mammals incidental to sounds from the use of seismic airguns associated with the geophysical survey (NMFS Proposed Action).

NSF mitigation measures

NSF's mitigation measures included in the proposed action fall into two categories: procedural mitigation and geographic mitigation measures. Per the SRS, procedural mitigation primarily involves ramp-ups, dedicated observers during daylight operations, passive acoustic monitoring (PAM) during the day and night, and power downs when marine mammals or sea turtles are detected or are about to enter the exclusion zone.

LDEO "would use visual and acoustic monitors to conduct pre-activity monitoring for at least 30 minutes prior to beginning seismic operations. Following the pre-clearance period, the airgun array would be activated with a stepwise increase in the number of active elements (ramp-up) to warn animals of pending operations" (SRS p. 4). Airgun operations would shutdown if a marine mammal enters a designated exclusion zone (500m for all marine mammals, 1,500m for beaked whales and dwarf and pygmy sperm whales, and any distance for all large whales with calves, aggregations of six or more large whales, a North Pacific right whale, or a killer whale observed).

Furthermore, airgun operations would also shutdown for killer whale vocalizations detected on the PAM system.

To enhance southern resident killer whale (SRKW) protections, geographic mitigation will be implemented for surveys between Tillamook Head, OR and Barkley Sound, BC within the 200-meter depth contour to be conducted in daylight hours only. Furthermore, a second vessel with additional observers will travel ahead of the survey vessel. The tracklines have also been revised to limit the ensonified area from extending within the 100-meter depth contour in this region due to the high estimated densities of SRKW.

Reduction of vessel speed to 10 knots or less is proposed to prevent ship strikes when mother/calf pairs, pods, or large assemblages of marine mammals are observed. Vessels would maintain a distance of 100 meters from large whales (mysticetes, sperm whales, and killer whales) and 50 meters from all other marine mammals (except those voluntarily approaching the vessel).

NSF monitoring measures

The SRS does not describe any general monitoring provisions specific to NSF activities that would enhance understanding of impacts to marine mammals and other affected species, despite NMFS acknowledgement of monitoring as a key component of adaptive management.

II. *NSF and NMFS Conclusions Regarding the Effects of the Proposed Action on Sanctuary Resources*

NSF and NMFS analyses of potential overlap of activities and sanctuary resources indicate likely injury to sanctuary resources inside the sanctuary due to sound and energy producing activities occurring both inside and outside the sanctuary's boundary. Acoustic impacts from airguns are identified as likely to injure marine mammals, sea turtles, fish, marine invertebrates, and seabirds. However, NMFS and NSF conclude that the proposed activities would not adversely affect or significantly impact marine invertebrates, fish, and fisheries. Furthemore, due to the short-term exposures, the proposed activities would have no significant impact on marine mammals, sea turtles, or seabirds. Specifically, NSF and NMFS find that acoustic exposure resulting from the geophysical survey could result in permanent threshold shifts (hearing damage) to three marine mammal species in the sanctuary: humpback whales, harbor porpoise, and Dall's porpoise. NSF and NMFS further document exposures from the geophysical survey that could result in temporary hearing damage or behavioral responses in 24 marine mammal populations while present in the sanctuary. Predictions for numbers of exposure events per population in the sanctuary range from hundreds of harbor porpoises, Dall's porpoises and Steller sea lions, to dozens of Risso's dolphins and California sea lions to single digits of SRKW, humpback whales, gray whales, fin whales, and blue whales (see Table 3 from SRS).

In total, NSF and NMFS predict that 1,388 instances of marine mammal take per year (21 of which are Level A harassment) will occur in OCNMS as a result of proposed activities for 2021 across 24 species. NMFS and NSF find that levels of impact from the survey within the sanctuary will have only negligible impacts on the affected species or stocks of marine mammals.

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It is important to note that OCNMS overlaps several marine mammal biologically important areas (BIAs), as well as proposed critical habitat areas that may provide a greater conservation benefit to the species than other areas within the sanctuary. These areas include:

- Northern Washington humpback feeding BIA (May-Nov);
- Northeast Washington Gray Whale Feeding BIA (May-Nov);
- Gray whale Migration BIA Northbound – Phase A (Jan-Jul);
- Gray whale Migration BIA Northbound – Phase B (Mar-Jul);
- Gray whale Migration BIA Southbound – All (Oct-Mar);
- Gray whale Migration BIA- potential presence (Jan-Jul; Oct-Dec);
- Proposed Southern Resident killer whale critical habitat Area 1 and Area 2; and
- Proposed humpback whale critical habitat.

III. NMSA Injury Determination

Section 304(d) of the NMSA (16 U.S.C. § 1434(d)) requires federal agencies to consult with the Secretary of Commerce regarding any federal action or proposed action, including activities authorized by federal license, lease, or permit, that is likely to destroy, cause the loss of, or injure[1] any sanctuary resource. A portion of the proposed geophysical survey activities will occur within and in close proximity to OCNMS and will result in impacts including Level A and Level B harassment of marine mammals (take[2]), which NMFS is proposing to authorize under the MMPA. ONMS concurs with NMFS and NSF's conclusion that Level A and Level B takes of marine mammals occurring in the sanctuary as a result of survey activities constitute injury as defined under the NMSA.

While NSF and NMFS find that sound and energy produced by the geophysical survey and their direct effects on marine mammals are the focus of this consultation, ONMS remains concerned about impacts to other sanctuary resources such as sea turtles, seabirds, and fish. As such, ONMS is actively engaged in research to better understand fish movement and behavior within sanctuary waters, particularly soniferous species such as rockfishes and endangered and keystone species such as salmon. ONMS is engaged with partners to better understand the acoustic behavior and potential impacts of anthropogenic noise for more acoustically sensitive fish species in the sanctuary. Salmon, however, continue to represent a species of elevated interest for research relative to the impacts of acoustic activities offshore, given their role as key prey for critically endangered SRKW.

[1] The NMSA regulations define "to injure" as "to change adversely, either in the short or long term, a chemical, biological or physical attribute of, or the viability of. This includes, but is not limited to, to cause the loss of or destroy." 15 CFR 922.3. Throughout this letter reference to the word "injury" means "injury" as defined under the NMSA.

[2] Take (as discussed in the SRS and in NMFS' proposed rule) is an estimate of potential impact to marine mammals adjusted to reflect implementation of proposed mitigation. While 'take' does not necessarily account for all injuries to marine mammals, as a basis for initiating NMSA 304(d) consultation, take occurring within the sanctuary has been considered "likely" injury by NMFS and NSF and thus will be considered in our injury analysis.

Based on our evaluation of material provided in the SRS and associated EA, ONMS concurs with NMFS and NSF's conclusion that Level A and Level B takes of marine mammals occurring in the sanctuary as a result of the proposed geophysical survey constitute injury as defined under the NMSA. ONMS is aware that take estimates represent conservative predictions for the maximum number of exposure "events" that could happen during the survey. For each population, the number 25 captures both 25 exposures to one animal in one day in one year and 25 different individuals each exposed once over the course of the survey, and every combination in between. Take is therefore an important quantification and means to explore the possible efficacy of mitigation strategies. However, take is a less useful tool for providing a holistic representation of actualized impacts to OCNMS's resources and qualities.

ONMS is providing NMFS and NSF with the following recommended alternatives to heighten mitigation for SRKW in the sanctuary due to their critically endangered status and use of OCNMS offshore waters.

IV. NMSA Section 304(d) Recommended Alternatives

ONMS recommends that NSF and NMFS implement the following recommended alternatives to protect sanctuary resources during its proposed geophysical survey activities:

1. ***Reduction in take of vulnerable marine mammal stocks within the sanctuary via enhancements of procedural mitigation to daylight hour operations within OCNMS***

ONMS recommends an enhancement of the current procedural mitigation measures to reduce potential injury to marine mammals due to higher density of occurrence within the sanctuary. The sanctuary overlaps humpback and gray whale areas of biological importance, as well as portions of proposed critical habitat for SRKW and humpback whales. National marine sanctuaries are designated due to the special national, and in some cases international, significance of their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational, and/or esthetic qualities. National marine sanctuaries require a higher standard of resource protection than other marine waters. Furthermore, the usual and accustomed fishing grounds of the coastal treaty tribes fully overlap the sanctuary, exemplifying the productivity and uniqueness of this region.

ONMS recommends the augmentation of operations within OCNMS to be restricted to daylight hours only regardless of depth. NSF is currently proposing to limit "survey operations to daylight hours only…in waters 200-m or less between Tillamook Head, OR and Barkley Sound, BC" as this "is expected to increase the ability of PSOs to visually detect Southern Resident killer whales and initiate shutdowns to minimize exposures" (SRS p. 8). NSF is planning to survey 149.7km of OCNMS, of which 47.1km (31.5%) of the tracklines are deeper than 200-m and therefore would not be covered under the existing mitigation measure. There is limited information on the distribution of SRKW on the outer Washington coast. Due to the extreme fragility of this stock we are recommending enhanced precautions to limit exposures of the survey within the full extent of the sanctuary. By restricting activities within the sanctuary to daylight hours, the ability to

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visually detect marine mammals and initiate shutdowns to minimize exposures will be enhanced during survey operations in this highly productive region.

2. ***Reduction in take of vulnerable marine mammal stocks within the sanctuary through utilization of a secondary observer vessel throughout OCNMS***

As mentioned in our previous recommendation, OCNMS is a highly productive region for marine mammals, including listed species under the ESA.

ONMS recommends the augmentation of operations within OCNMS to have continuous utilization of protected species observers (PSOs) on the second vessel operating ahead of the R/V *Marcus G. Langseth* within the sanctuary regardless of depth. NSF currently proposes "survey operations…requiring a second vessel with additional PSOs to travel ahead of the Langseth in waters 200-m or less between Tillamook Head, OR and Barkley Sound, BC" as this "is expected to increase the ability of PSOs to visually detect Southern Resident killer whales and initiate shutdowns to minimize exposures" (SRS p. 8). However, nearly one-third of the tracklines within OCNMS are deeper than 200-m and therefore would not be covered under the existing mitigation. As previously noted, our understanding of SRKW distribution on the outer Washington coast is limited. Due to the extreme fragility of this stock we are recommending enhanced precautions to limit exposures of the survey within the full extent of the sanctuary given the high productivity of this region. By requiring the continuous use of PSOs on the second vessel regardless of depth in OCNMS, the ability to visually detect marine mammals and initiate shutdowns to minimize exposures will be enhanced during survey operations.

V. NMSA Monitoring and Reporting Recommendation

Several programs are being actively developed to better share information regarding the presence of individual SRKW due to their critically endangered status. The Whale Report Alert System, although currently not well populated for offshore waters, is likely to see advancements in the coming years and would provide another resource for mitigation response in OCNMS for this stock. In turn, NSF observations would provide a form of data input in offshore waters that would be of value for the alert system as a whole. We therefore recommend that NSF consider investment in this system as a user when the distribution of information becomes relevant for offshore operations.

VI. Tribal Consultation and Notification

Pursuant to Executive Order 13175 and NOAA Procedures for Government-to-Government Consultation with Federally Recognized Indian Tribes and Alaska Native Corporations, ONMS has developed a 304(d) consultation protocol with the Makah Tribe to ensure timely, meaningful discussion during the 304(d) process. In compliance with ONMS 304(d) consultation protocol with the Makah Tribe, ONMS notified the Makah Tribe of the NSF and NMFS submission of a SRS, as well as provided the completed SRS and initiated formal communication on this proposed federal action on January 27, 2021. On February 22, 2021, ONMS and Makah staff consulted on the completed SRS, ONMS recommendations, tribal interests, and shared priorities. The Makah Tribe submitted a written response supporting ONMS recommendations on March 4,

2021. The Makah Tribe's input has been integrated into ONMS recommendations, where applicable. ONMS also shared the completed SRS with tribal staff at Quinault Indian Nation, Hoh Tribe, and Quileute Tribe on January 28, 2021.

The high productivity of this region has supported tribal subsistence and commerce for thousands of years. The 1855 Treaty of Neah Bay with the Makah Indian Tribe and the 1856 Treaty of Olympia with the Hoh Indian Tribe, Quileute Indian Tribe, and the Quinault Indian Nation reserved the "right of taking fish[3] at all usual and accustomed grounds and stations," into perpetuity. The treaties were a grant of rights from the tribes and a reservation of rights not granted. The Hoh, Makah, and Quileute Tribes and Quinault Indian Nation (hereinafter the coastal treaty tribes) have treaty-reserved rights off reservation, including usual and accustomed fishing grounds (U&As) that extend 30–40 nautical miles offshore in which commercial, subsistence, and ceremonial fisheries occur. The U&As of the coastal treaty tribes fully overlap the sanctuary.

Several of the coastal treaty tribes (Makah, Quileute, and Quinault) have expressed concerns on impacts to treaty-reserved fisheries and have requested coordinated communications from the survey vessel with their respective fisheries departments when approaching their U&As to avoid or minimize impacts. To facilitate this coordination in communications, below are the tribal staff we recommend NSF coordinate with to avoid and minimize adverse impacts.

<u>Hoh Tribe:</u>
- Wendy Largent, Natural Resources Director: wendy.largent@hohtribe-nsn.org, (360) 780-0010
- Julie Ann Koehlinger, Timber, Fish, and Wildlife Biologist: julie.koehlinger@hohtribe-nsn.org, (360) 780-0551
- Brian Hoffman, Fisheries Management Biologist: brian.hoffman@hohtribe-nsn.org, (360) 780-2008

<u>Makah Tribe:</u>
- Ray Colby, Assistant Fisheries Director: ray.colby@makah.com, (360) 640-4262
- Will Jasper, Groundfish Biologist: william.jasper@makah.com, (360) 640-1662
- Tiffany Petersen, Salmon Biologist: tiffany.petersen@makah.com, (360) 640-3047
- Jonathan Scordino, Marine Mammal Biologist: jon.scordino@makah.com, (360) 640-0959

<u>Quileute Tribe:</u>
- Frank Geyer, Natural Resources Director: frank.geyer@quileutetribe.com, (360) 374-2027
- Jennifer Hagen, Marine Policy Advisor: jennifer.hagen@quileutetribe.com, (360)- 640-4430

[3] The Treaty of Neah Bay has unique language reserving Makah's right to "whaling and sealing" in addition to fish.

6

Quinault Indian Nation:

- Joe Schumacker, Marine Resources Scientist: jschumacker@quinault.org, (360) 590-0162
- Scott Mazzone, Shellfish/Marine Fish Biologist: smazzone@quinault.org, (360) 590-0293
- Alan Sarich, Marine Finfish Biologist: asarich@quinault.org, (360) 591-4946

VII. Next Steps for Consultation

Consistent with section 304(d)(3) of the NMSA, once NSF and NMFS have had an opportunity to consider our recommended alternatives, please engage ONMS for further consultation. Should NSF and NMFS decide not to follow our recommended alternatives (as provided herein or modified in further consultation), please provide ONMS with a written statement documenting your decisions and rationale. Finally, pursuant to section 304(d)(4) of the NMSA, if NSF and NMFS takes an action other than those recommended herein, and such action results in injury to a sanctuary resource, the heads of NSF and NMFS are required to promptly prevent and mitigate further damage, and restore or replace the sanctuary resources in a manner approved by ONMS.

This consultation applies to the proposed action as defined in NSF's draft Environmental Assessment and NMFS's proposed incidental harassment authorization. NSF and NMFS must reinitiate consultation with ONMS if either agency determines that they trigger the NMSA's consultation requirements. Specifically:

- If the action is modified such that it is likely to destroy, cause the loss of, or injure a sanctuary resource or quality in a manner different or greater than was considered in a previous consultation under section 304(d) of the NMSA; or
- If the action is likely to destroy, cause the loss of, or injury a sanctuary resource or quality not considered in a previous consultation under 304(d); or
- If new information reveals that the action it is likely to destroy, cause the loss of, or injure a sanctuary resource or quality in a manner different or greater than considered in a previous consultation; or
- If a new action is proposed that is likely to destroy, cause the loss of, or injure a sanctuary resource.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE

Olympic Coast National Marine Sanctuary
115 E. Railroad Ave., Suite 301
Port Angeles, Washington 98362

April 1, 2021

Dr. Sean Higgins
Columbia University Lamont-Doherty Earth Observatory
61 Route 9W
Office of Marine Operations
Palisades, NY 10964

Dear Dr. Higgins:

The National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries (ONMS) has approved the issuance of permit number OCNMS-2020-001 to conduct activities within Olympic Coast National Marine Sanctuary (sanctuary) for research purposes. Activities are to be conducted in accordance with the permit application and all supporting materials submitted to the sanctuary, and the terms and conditions of permit number OCNMS-2020-001 (enclosed).

This permit is not valid until signed and returned to the ONMS. Retain one signed copy and carry it with you while conducting the permitted activities. Additional copies must be signed and returned, by either mail or email, to the following individual within 30 days of issuance and before commencing any activity authorized by this permit:

Katie Wrubel
Permit Coordinator
Olympic Coast National Marine Sanctuary
115 E. Railroad Ave , Suite 301
Port Angeles, Washington 98362
Katie.Wrubel@noaa.gov

Your permit contains specific terms, conditions and reporting requirements. Review them closely and fully comply with them while undertaking permitted activities.

If you have any questions, please contact Katie Wrubel at Katie.Wrubel@noaa.gov. Thank you for your continued cooperation with the ONMS.

Sincerely,

Carol Bernthal

Carol Bernthal
Superintendent

Enclosure

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE

Olympic Coast National Marine Sanctuary
115 E. Railroad Ave., Suite 301
Port Angeles, Washington 98362

OLYMPIC COAST NATIONAL MARINE SANCTUARY
RESEARCH PERMIT

Permittee:
Dr. Sean Higgins
Columbia University Lamont-Doherty Earth Observatory
61 Route 9W
Office of Marine Operations
Palisades, NY 10964

Permit Number: OCNMS-2020-001
Effective Date: May 1, 2021
Expiration Date: August 31, 2021

Project Title: Collaborative Research: Illuminating the Cascadia plate boundary zone and accretionary wedge with a regional-scale ultra-long offset multi-channel seismic study

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This permit is issued for activities in accordance with the National Marine Sanctuaries Act (NMSA), 16 USC §§ 1431 *et seq.*, and regulations thereunder (15 CFR Part 922). All activities must be conducted in accordance with those regulations and law. No activity prohibited in 15 CFR Part 922 is allowed except as specified in the activity description below.

Subject to the terms and conditions of this permit, the National Oceanic and Atmospheric Administration (NOAA), Office of National Marine Sanctuaries (ONMS) hereby authorizes the permittee listed above to conduct research activities within Olympic Coast National Marine Sanctuary (OCNMS or sanctuary). All activities are to be conducted in accordance with this permit and the permit application received December 17, 2019. The permit application is incorporated into this permit and made a part hereof; provided, however, that if there are any conflicts between the permit application and the terms and conditions of this permit, the terms and conditions of this permit shall be controlling.

Permitted Activity Description:
The following activities are authorized by this permit:

Deployment of 3 ocean bottom seismometers and abandonment of concrete anchors.

No further activities prohibited by sanctuary regulations are allowed.

Permitted Activity Location:
The permitted activity is allowed only in the following location(s):

Approximate coordinates for the OBS deployments within the Olympic Coast National Marine Sanctuary (OCNMS) would be as follows:

Higgins
Permit # OCNMS-2020-001
Page 2 of 6

Line	OBS	Lon	Lat	Depth (m)
22	113	-124.92642	47.22340	586.2
22	114	-124.80873	47.24203	149.3
22	115	-124.69096	47.26055	105.1

Special Terms and Conditions:

1. This permit is effective from either May 1, 2021 or the day it is signed by the permittee and delivered to the OCNMS Permit Coordinator (see General Terms and Condition #1), whichever is later. The executed permit will be valid through August 31, 2021. The permittee may request an amendment from the OCNMS Superintendent a minimum of 60 days in advance of this expiration date, to extend the effective date of this permit. Amendments to this permit cannot be made after expiration.

2. This permit does not relieve the permittee of responsibility to comply with all other federal, state and local laws and regulations.

3. While in, or adjacent to, the sanctuary strict compliance to mitigations outlined in the Marine Mammal Protection Act (MMPA) incidental harassment authorization (IHA) are required as well as the recommended alternatives agreed upon under National Marine Sanctuaries Act (NMSA) 304(d) consultation and requirements under Endangered Species Act consultations. In addition to IHA mitigations, daily contact between NMFS Protected Resources Division and the protected species observers shall be established.

4. As agreed under NMSA 304(d) consultation, while within OCNMS survey activities will be restricted to daylight hours only with sufficient visibility to enhance efficacy of protected species observers. Furthermore, while in OCNMS, regardless of depth, a secondary support vessel aiding in protected species observations will be utilized.

5. The OCNMS Permit Coordinator (see General Terms and Condition #1) shall be notified at least 72-hours in advance, and at the conclusion, of any field operations conducted under this permit. Notification shall include a brief description of the planned operations and schedule.

6. The Permittee will provide ship-based and shore side contacts to the OCNMS Permit Coordinator. The Permittee will provide notice when the R/V *Oceanus* will be deploying the ocean bottom seismometers as well as when the R/V *Marcus G. Langseth* is underway. This notice should include the anticipated schedule for approaching the sanctuary. The permittee will also provide notice a minimum of 72-hours prior to entering OCNMS boundaries to the OCNMS Permit Coordinator.

7. When approaching tribal usual and accustomed fishing grounds (U&As), the survey vessel should communicate directly with their respective fisheries departments a minimum of 72-hours in advance to avoid or minimize impacts. To facilitate this coordination in communications below are the tribal staff we recommend NSF coordinate with to avoid and minimize adverse impacts:

Higgins
Permit # OCNMS-2020-001
Page 3 of 6

- Quinault Indian Nation:
  - Joe Schumacker, Marine Resources Scientist: jschumacker@quinault.org, (360) 590-0162
  - Scott Mazzone, Shellfish/Marine Fish Biologist: smazzone@quinault.org, (360) 590-0293
  - Alan Sarich, Marine Finfish Biologist: asarich@quinault.org, (360) 591-4946

- Hoh Tribe:
  - Wendy Largent, Natural Resources Director: wendy.largent@hohtribe-nsn.org, (360) 780-0010
  - Julie Ann Koehlinger, Timber, Fish, and Wildlife Biologist: julie.koehlinger@hohtribe-nsn.org, (360) 780-0551
  - Brian Hoffman, Fisheries Management Biologist: brian.hoffman@hohtribe-nsn.org, (360) 780-2008

- Quileute Tribe:
  - Frank Geyer, Natural Resources Director: frank.geyer@quileutetribe.com, (360) 374-2027
  - Jennifer Hagen, Marine Policy Advisor: jennifer.hagen@quileutetribe.com, (360)-640-4430

- Makah Tribe:
  - Ray Colby, Assistant Fisheries Director: ray.colby@makah.com, (360) 640-4262
  - Will Jasper, Groundfish Biologist: william.jasper@makah.com, (360) 640-1662
  - Tiffany Petersen, Salmon Biologist: tiffany.petersen@makah.com, (360) 640-3047
  - Jonathan Scordino, Marine Mammal Biologist: jon.scordino@makah.com, (360) 640-0959

8. The permit holder will contact the U.S. Naval Air Station Whidbey Island Community Planning & Liaison Officer for the Northwest Training Range Complex (NWTRC) a minimum of 48 hours prior to the planned arrival on the first air gun array survey line. The permit holder is required to work with the U.S. Navy to avoid conflicts with naval operations. The current contact is Ms. Kimberly Peacher, who can be reached at (360) 930-4085 (work cell) or kimberly.peacher@navy.mil. The OCNMS permit coordinator should be informed of any communication and agreements between the U.S. Navy and the permit holder.

9. The permittee shall maintain contact with the U.S. Coast Guard D13 Waterways Management Branch regarding the location of the ocean bottom seismometers, to ensure that they are properly identified on the nautical charts and/or noticed in the "Local Notice to Mariners", as appropriate. Copies of any correspondence, example "Local Notice to Mariners" notice, or other permit or authorization shall be provided to the OCNMS Permit Coordinator (see General Terms and Condition #1).

10. Operations within the International Maritime Organization (IMO) Area to be Avoided (ATBA) or within the traffic lanes are to be conducted in coordination with the United States

Coast Guard Seattle Traffic or Canadian Coast Guard Prince Rupert Traffic, as appropriate.

11. During activities authorized by this permit, the permittee shall display, when appropriate, international signals for conducting special operations, monitor VHF radio and attempt to establish bridge-to-bridge communications with all approaching commercial shipping traffic to advise them of restricted maneuverability and to arrange passing and/or closest point of approach.

12. Within 30 days of completion of each installation, servicing or retrieval event, the permittee shall submit a brief, written report on the permitted activities within OCNMS, including revised coordinates (if the instrument location is not consistent with its proposed coordinates) and a description of materials abandoned on the seafloor. Please send this report to Katie Wrubel, OCNMS Permit Coordinator, via email (katie.wrubel@noaa.gov).

13. The permittee is required to recover all equipment, with the exception of three concrete anchors. If equipment is not recovered a report describing the failed attempted recovery, detailed description of the abandoned equipment, its location, and plans for future recovery attempts shall be provided to the OCNMS Permit Coordinator within 2 weeks of the incident. At no time may hazardous materials, including batteries, be discarded within the sanctuary.

14. No activity authorized by this permit shall disturb or impact any historical or marine archaeological resources of the sanctuary. If historical or marine archaeological resources are encountered at any time, the permittee shall cease all further activities under this permit and immediately contact the OCNMS Permit Coordinator (see General Terms and Condition #1).

15. Data and results from the survey should be made available within a reasonable timeframe. The permittee should present the results of the survey to the Olympic Coast communities and can work with OCNMS on identifying avenues for outreach (i.e., Sanctuary webinar series, Sanctuary Advisory Council meeting, or other venues).

16. The permittee shall submit final report of all activities conducted under this permit to the OCNMS Permit Coordinator (see General Terms and Condition #1) no later than December 31 of 2021. The report should include information regarding permitted activities such as servicing dates, problems encountered, lost equipment, and disturbance of historical artifacts. There should be a section that documents lost equipment that has not been recovered to date, this should include equipment that was lost under previous permits related to the same project, if applicable.

17. The permittee shall submit a report of the survey findings within a reasonable amount of time following completion of the survey. This report should be provided to the OCNMS Permit Coordinator and the coastal treaty tribes (see Special Condition #7 for contacts).

General Terms and Conditions:

1. Within 30 (thirty) days of the date of issuance, the permittee must sign and date this permit for it to be considered valid. Once signed, the permittee must send copies, via mail or email, to the following individual:

   Katie Wrubel
   Permit Coordinator
   Olympic Coast National Marine Sanctuary
   115 E. Railroad Ave , Suite 301
   Port Angeles, Washington 98362
   Katie.Wrubel@noaa.gov

2. It is a violation of this permit to conduct any activity authorized by this permit prior to the ONMS having received a copy signed by the permittee.

3. This permit may only be amended by the ONMS. The permittee may not change or amend any part of this permit at any time. The terms of the permit must be accepted in full, without revision; otherwise, the permittee must return the permit to the sanctuary office unsigned with a written explanation for its rejection. Amendments to this permit must be requested in the same manner the original request was made.

4. All persons participating in the permitted activity must be under the supervision of the permittee, and the permittee is responsible for any violation of this permit, the NMSA, and sanctuary regulations for activities conducted under, or in conjunction with, this permit. The permittee must assure that all persons performing activities under this permit are fully aware of the conditions herein.

5. This permit is non-transferable and must be carried by the permittee at all times while engaging in any activity authorized by this permit.

6. This permit may be suspended, revoked, or modified for violation of the terms and conditions of this permit, the regulations at 15 CFR Part 922, the NMSA, or for other good cause. Such action will be communicated in writing to the applicant or permittee, and will set forth the reason(s) for the action taken.

7. This permit may be suspended, revoked or modified if requirements from previous ONMS permits or authorizations issued to the permittee are not fulfilled by their due date.

8. Permit applications for any future activities in the sanctuary or any other sanctuary in the system by the permittee might not be considered until all requirements from this permit are fulfilled.

9. This permit does not authorize the conduct of any activity prohibited by 15 CFR Part 922, other than those specifically described in the "Permitted Activity Description" section of this permit. If the permittee or any person acting under the permittee's supervision

conducts, or causes to be conducted, any activity in the sanctuary not in accordance with the terms and conditions set forth in this permit, or who otherwise violates such terms and conditions, the permittee may be subject to civil penalties, forfeiture, costs, and all other remedies under the NMSA and its implementing regulations at 15 CFR Part 922.

10. Any publications and/or reports resulting from activities conducted under the authority of this permit must include the notation that the activity was conducted under National Marine Sanctuary Permit OCNMS-2020-001 and be sent to the ONMS official listed in general condition number 1.

11. This permit does not relieve the permittee of responsibility to comply with all other federal, state and local laws and regulations, and this permit is not valid until all other necessary permits, authorizations, and approvals are obtained. Particularly, this permit does not allow disturbance of marine mammals or seabirds protected under provisions of the Endangered Species Act, Marine Mammal Protection Act, or Migratory Bird Treaty Act. Authorization for incidental or direct harassment of species protected by these acts must be secured from the U.S. Fish and Wildlife Service and/or NOAA Fisheries, depending upon the species affected.

12. The permittee shall indemnify and hold harmless the Office of National Marine Sanctuaries, NOAA, the Department of Commerce and the United States for and against any claims arising from the conduct of any permitted activities.

13. Any question of interpretation of any term or condition of this permit will be resolved by NOAA.

Your signature below, as permittee, indicates that you accept and agree to comply with all terms and conditions of this permit. This permit becomes valid when you, the permittee, countersign and date below. Please note that the expiration date on this permit is already set and will not be extended by a delay in your signing.

Sean Higgins — 4/12/21

Dr. Sean Higgins — Date
Columbia University Lamont-Doherty Earth Observatory

Carol Bernthal — 04/01/2021

Carol Bernthal — Date
Superintendent
Olympic Coast National Marine Sanctuary

0 document(s) attached.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE
OFFICE OF NATIONAL MARINE SANCTUARIES
Olympic Coast National Marine Sanctuary
115 East Railroad Avenue, Suite 301
Port Angeles, WA 98362-2925

January 27, 2021

Amy Fowler
Incidental Take Program
National Marine Fisheries Service Office of Protected Resources
1315 East-West Highway
Silver Spring, MD 20910

Holly Smith
National Science Foundation
2415 Eisenhower Avenue
Alexandria, Virginia 22314

Dear Ms. Fowler, Ms. Smith:

On May 1, 2020, the National Oceanic and Atmospheric Administration (NOAA) Office of National Marine Sanctuaries (ONMS) received the National Science Foundation (NSF) and NOAA National Marine Fisheries Service (NMFS) initial Sanctuary Resource Statement (SRS) and request to initiate consultation under the National Marine Sanctuaries Act (NMSA; 16 U.S.C. 1434) for a proposed marine geophysical survey of the Cascadia Subduction Zone in the northeast Pacific Ocean using the R/V *Marcus G. Langseth*. The proposed action includes the associated notice of proposed rulemaking by NMFS to issue incidental take authorizations under the Marine Mammal Protection Act (MMPA) to Lamont-Doherty Earth Observatory for takes of marine mammals incidental to the geophysical surveys (April 7, 2020; 85 FR 19580). The SRS references the permit application to Olympic Coast National Marine Sanctuary (OCNMS) initially submitted on December 17, 2019 and a Draft Environmental Assessment prepared by NSF (dated November 21, 2019). After ONMS's request for additional information and clarification, ONMS received a final revised permit application on May 15, 2020 and a final revised SRS on January 22, 2021.

Pursuant to section 304(d) of the NMSA, ONMS conducted a review of the revised SRS and referenced documents and finds that it is sufficient for the purposes of making an injury determination and developing recommended alternatives. The next step in the consultation process is for ONMS to evaluate whether OCNMS resources are likely to be injured by the proposed action, and if so to develop any necessary reasonable and prudent alternatives to protect sanctuary resources. Consistent with NOAA's government-to-government consultation responsibilities with the Makah Tribe, ONMS will share a copy of the SRS with the Makah Tribe and initiate discussions regarding technical/policy input on any potential recommended alternatives. ONMS will complete this work within 45 days of the date of this letter, no later than March 12, 2021.

If you have any questions, please contact Katie Wrubel at katie.wrubel@noaa.gov.

Sincerely,

Carol Bernthal

Carol Bernthal
Sanctuary Superintendent
Olympic Coast National Marine Sanctuary

cc: Vicki Wedell, NOAA Office of National Marine Sanctuaries
Sophie Godfrey-McKee, NOAA Office of National Marine Sanctuaries
Leila Hatch, NOAA Office of National Marine Sanctuaries
George Galasso, NOAA Olympic Coast National Marine Sanctuary
Katie Wrubel, NOAA Olympic Coast National Marine Sanctuary

APPENDIX I: CANADIAN FISHERIES ACT - DFO LETTER OF ADVICE

Fisheries and Oceans Canada
Pacific Region
Ecosystem Management Branch
3190 Hammond Bay Road
Nanaimo, BC
V9T 6N7

Pêches et Océans Canada
Région du Pacifique
Gestion des ecosystems
3190, rue Hammond Bay
Nanaimo, (C.-B.)
V9T 6N7

April 6, 2021

Your file *Votre référence*
NSF Cascadia Subduction Zone Seismic Survey

Our file *Notre référence*
20-HPAC-01328

Sean Higgins
Director, Office of Marine Operations
Lamont-Doherty Earth Observatory (LDEO) of Columbia University
61 Route 9 West
Palisades, New York, USA 10964

Via email: sean@ldeo.columbia.edu

Dear Mr. Higgins:

Subject: National Science Foundation (NSF) Marine Seismic Survey of the Cascadia Subduction Zone, May 01 – July 10, 2021.

Fisheries and Oceans Canada (DFO) received your proposal on December 18, 2020. We understand that you propose to conduct high-energy seismic surveys from the Research Vessel (R/V) Marcus G. Langseth (Langseth) in combination with Ocean Bottom Seismometers (OBS) at the Cascadia Subduction Zone in the Northeast Pacific Ocean off the west coast of Vancouver Island during late spring/summer 2021. In particular:

- The proposed two-dimensional (2-D) seismic surveys will occur over an estimated 16 days within the Exclusive Economic Zone (EEZ) of Canada and Canadian Territorial Waters.
- The R/V Langseth will cruise at 7.8 km/h (4.2 kt) and deploy a 36-airgun towed array (12 m depth: 37.5 m shot interval) with a total discharge volume of ~6600 in^3 in water depths ranging from 60–4400 m.
- The array will have a sound output equivalent to 250 dB RMS (root mean square) re: 1 μPa which is above the sound pressure level (160 dB RMS re: 1 μPa) that can result in the temporary threshold shift in the hearing of marine mammals.
- The receiving system will consist of a 15 km long hydrophone streamer.
- In addition to the operation of the towed array and hydrophone streamer, the R/V Langseth will operate a multibeam echosounder, a sub-bottom profiler and an acoustic Doppler current profiler continuously during the seismic survey.

Canada

We understand a number of aquatic species listed under the *Species at Risk Act* (SARA) may use the area in the vicinity of where your proposed activities are to be carried out. These listed species include the endangered Southern Resident Killer Whale.

Our review considered the following information:

- DFO Request for Review form dated December 18, 2020; and
- Draft *Environmental Assessment/Analysis (EA/A) of a Marine Geophysical Survey by R/V Marcus G Langseth of the Cascadia Subduction Zone in the Northeast Pacific Ocean, Late Spring/Summer 2020* dated November 21, 2019, prepared by LGL Ltd (King City, Ontario).

Your proposal has been reviewed to determine whether it is likely to result in:

- the death of fish by means other than fishing and the harmful alteration, disruption or destruction of fish habitat which are prohibited under subsections 34.4(1) and 35(1) of the *Fisheries Act*; and
- effects to listed aquatic species at risk, any part of their critical habitat or the residences of their individuals in a manner which is prohibited under sections 32, 33 and subsection 58(1) of the *Species at Risk Act*.

The aforementioned outcomes are prohibited unless authorized under their respective legislation and regulations.

DFO's review of the information provided indicates that there are a number of both listed and non-listed aquatic SARA species that are likely to be present or in the vicinity of the proposed seismic survey. As such, DFO recommends that avoidance of sensitive habitats and SARA-listed species be undertaken. However, given the nature of the proposed activities, such as the extent, location and timing of activities, avoidance measures may not always be possible. For example, using observers to avoid encounters with marine mammals may not always be effective given the physical limitations of observing animals during certain conditions, such as late spring/summer storms with Beaufort sea states > 3 and the proposed night-time operations. Killer Whales (all ecotypes: resident, transient, offshore) are known to have a strong behavioural reaction to intense mid-frequency noise and Southern Resident Killer Whales, in particular, are currently facing imminent threats to their survival and recovery from multiple factors including anthropogenic sound. Impacts on a small number of individuals can have serious population-level consequences if population numbers are already low, as in the case of the Southern Resident Killer Whales. In addition, the activities will occur adjacent to designated critical habitat of Southern and Northern Resident Killer Whales as well as in areas under consideration for critical habitat orders for Transient Killer Whales. The generation of noise is intrinsic to the survey methodology and will cause short term disturbance of marine mammals including temporary threshold shift (hearing) and masking (communication). Physical injury or harm/harassment is not anticipated, as generated noise will continue to trigger avoidance behaviour by both marine mammals and fish species as the R/V Langseth moves forward along the survey tracks at slow speed (7.8 km/h or 4.2 kt).

In addition to the potential for short term disturbance to the SARA-listed species as indicated above, DFO notes the following:

- Other marine mammal species, in addition to those SARA-listed species, may be found in the proposed survey area at all times of the year, and some are particularly sensitive to anthropogenic noise, such as the Sperm Whale and four species of Beaked Whales.
- Small cetacean species (i.e., dolphins and porpoises) are ubiquitous in the area of the planned activities and may be encountered at any time of the year.
- Impacts on a few individual animals of the following species may have serious population-level consequences if population abundance is low. In this regard, the Blue Whale, Sei Whale, Killer Whale (all ecotypes), North Pacific Right Whale, and Grey Whales from the Pacific Coast Feeding Group (two new populations designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada, and under consideration for listing under SARA as Endangered: Pacific Coast Feeding Group, and Western Pacific) are at greater risk of long-term negative impacts because of their low population numbers.
- Due to the specifics of sound propagation in shallow (<100 m) versus deep water (>100m) there is a considerable risk of harm to all cetaceans in shallow waters from seismic survey sources, but specifically from low frequency and mid-frequency sources of noise. There is additional risk of harm to species such as the Blue Whale and Sei Whale at medium and deeper water depths.

The submitted EA/A report describes the monitoring and mitigation measures that the proponent proposes to undertake during the seismic survey. These measures are generally consistent with current standards including those outlined in the *Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment* (SCP attached). However, given that mitigation measures outlined in the SCP are intended as minimum requirements and considering the large size of the airgun array to be employed and the likely presence of SARA-listed species, it is imperative that additional mitigation measures be followed to reduce the risk to marine mammals.

Should the NSF proceed with the Cascadia Subduction Zone Seismic Survey, DFO recommends that the NSF implement additional mitigation measures such that the activities will avoid or minimize impacts and adverse effects to SARA-listed individuals and populations and avoid the destruction of critical habitat. DFO also recommends implementing all reasonable alternatives to those activities that have an adverse effect.

To avoid causing the death of fish (including marine mammals) and/or the harmful alteration, disruption, or destruction of fish habitat, or causing prohibited effects to aquatic species at risk, DFO recommends that the mitigation measures listed in the attached document and the submitted EA/A document be implemented along with the following mitigation and avoidance measures.

The most stringent measure should be implemented where appropriate:

- Conduct seismic survey activities outside of designated Killer Whale Critical Habitat (KWCH) with a setback that ensures that the estimated sound pressure level has diminished to ≤160 dB RMS re: 1 µPa for the shortest distance to the boundary of KWCH.
- Initiate an immediate and complete shutdown of the airgun array if a Killer Whale (all ecotypes), Northern Pacific Right Whale, whale with calf (any species) or aggregation of whales (any species) is observed.
- Initiate an immediate and complete shutdown of the airgun array if a Sperm Whale or a beaked whale (any species) is sighted within 1500 m of the airgun array.
- For other observations of marine mammals and/or turtles, initiate an immediate and complete shutdown of the airgun array if these animals are observed within an established exclusion zone with a radius of 1000 m.
- Refrain from conducting seismic surveys in waters less than 100 m in depth.
- Conduct seismic surveys in waters 100 to 200 m deep during daylight hours only, with a second vessel having two marine mammal observers on watch, positioned 5 km ahead of the R/V Langseth.
- Combine enhanced visual observations (e.g., reticle and big-eye binoculars, night vision devices and digital cameras) with non-visual detection methods (e.g., infrared technology (FLIR) and passive acoustic monitoring) to increase the likelihood of detecting marine mammals during ramp up, Beaufort sea states >3, and during night time survey operations.
- Monitor the established exclusion zone with a radius of 1000 m for 60 minutes prior to initial start-up of the airgun array or resumption of operations following a complete shutdown to allow for the detection of deep diving animals.

It remains your responsibility to remain in compliance with the *Fisheries Act* and the *Species at Risk Act*. It is also your Duty to Notify DFO if you have caused, or are about to cause, the death of fish (including marine mammals) by means other than fishing and/or the harmful alteration, disruption or destruction of fish habitat. Such notifications should be directed to the DFO-Pacific Observe, Record and Report phone line at 1-800-465-4336 or by email at DFO.ORR-ONS.MPO@dfo-mpo.gc.ca.

The protection of Southern Resident Killer Whales and other cetaceans is a priority for the Government of Canada. DFO and the Canadian Coast Guard (CCG) work with various stakeholders including the Province, First Nations, academia, and private industry partners to protect Southern Resident Killer Whales in British Columbia. Sightings of marine mammals by research vessels, such as the R/V Langseth, are typically provided to the CCG's Marine Mammal Desk at 1-833-339-1020 or via CCG radio. The Marine Mammal Desk reports whale sightings in real time and advises vessel traffic by providing enhanced situational awareness of the activities of Southern Resident Killer Whales and other cetaceans, such as humpback and grey whales. Sighting information is used to prevent vessel strikes, entanglements and other threats facing marine mammals.

DFO recognizes that this is a multi-vessel survey and that proposed activities may be carried out by vessels that are not under the direction of NSF personnel. To reduce impacts, DFO recommends that all relevant Cascadia Subduction Zone Seismic Survey participants be made aware of and implement the avoidance and mitigation measures listed above and in the attached document. Furthermore, DFO recommends that the NSF contact other Canadian federal authorities for advice on aspects of the survey that fall outside of DFO's expertise and mandate. It remains your responsibility to meet all other federal requirements that apply to your proposal.

Please note that the advice provided in this letter will remain valid for the period of the proposed activities. If you plan to execute your proposal after July 31, 2021, we recommend that you contact the Program to ensure that the advice remains up-to-date and accurate. Furthermore, the validity of the advice is also subject to there being no change in the relevant aquatic environment, including any legal protection orders or designations, during the period of activity.

If you have any questions with the content of this letter, please contact Steven Colwell at our Nanaimo office at 250 327-4763 or by email at Steven.Colwell@dfo-mpo.gc.ca. Please refer to the file number referenced above when corresponding with the Program.

Yours sincerely,

BRotinsky

Brenda Rotinsky
Watershed Operations Regulatory Manager
Fish and Fish Habitat Protection Program

Cc: Holly Smith, NSF, Alexandria, VA USA (hesmith@nsf.gov)

Attachment: *Statement of Canadian Practice with Respect to the Mitigation of Seismic Sound in the Marine Environment*

NATIONAL MARINE FISHERIES SERVICE
ENDANGERED SPECIES ACT SECTION 7
BIOLOGICAL AND CONFERENCE OPINION AND MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT RESPONSE

Title:	Biological and Conference Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation on the Lamont-Doherty Earth Observatory's Marine Geophysical Survey by the R/V *Marcus G. Langseth* of the Cascadia Subduction Zone in the Northeast Pacific Ocean and National Marine Fisheries Service Permits and Conservation Division's Issuance of an Incidental Harassment Authorization pursuant to Section 101(a)(5)(D) of the Marine Mammal Protection Act
Consultation Conducted By:	Endangered Species Act Interagency Cooperation Division, Office of Protected Resources, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce
Action Agency:	National Oceanic Atmospheric Administration National Marine Fisheries Service-Office of Protected Resources-Permits and Conservation Division
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1 INTRODUCTION

The Endangered Species Act of 1973 (ESA), as amended (16 U.S.C. 1531 et seq.) establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat they depend on. Section 7(a)(2) of the ESA requires Federal agencies to insure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their designated critical habitat. Federal agencies must do so in consultation with National Marine Fisheries Service (NMFS) for threatened or endangered species (ESA-listed), or designated critical habitat that may be affected by the action that are under NMFS jurisdiction (50 C.F.R. §402.14(a)). If a Federal action agency determines that an action "may affect, but is not likely to adversely affect" endangered species, threatened species, or designated critical habitat and NMFS concurs with that determination for species under NMFS jurisdiction, consultation concludes informally (50 C.F.R. §402.14(b)).

Section 7(b)(3) of the ESA requires that at the conclusion of consultation, NMFS provides an opinion stating whether the Federal agency's action is likely to jeopardize ESA-listed species or destroy or adversely modify designated critical habitat. If NMFS determines that the action is likely to jeopardize listed species or destroy or adversely modify critical habitat, NMFS provides a reasonable and prudent alternative that allows the action to proceed in compliance with section 7(a)(2) of the ESA. If an incidental take is expected, section 7(b)(4) requires NMFS to provide an incidental take statement (ITS) that exempts take incidental to an otherwise lawful action, and specifies the impact of any incidental taking, including reasonable and prudent measures (RPMs) to minimize such impacts and terms and conditions to implement the RPMs.

The Federal action agencies for this consultation are the National Science Foundation (NSF) and the NMFS's Permits and Conservation Division. Two federal actions are considered in this biological and conference opinion (opinion). The first is the NSF's proposal to fund a seismic survey on the Cascadia Subduction Zone in the Northeast Pacific Ocean to take place in May 2021, in support of an NSF-funded collaborative research project led by Columbia University's Lamont-Doherty Observatory (L-DEO). The second is the NMFS Permits and Conservation Division's proposal to issue an incidental harassment authorization (IHA) authorizing non-lethal "takes" by Level A and Level B harassment (as defined by the Marine Mammal Protection Act [MMPA]) of marine mammals incidental to the planned seismic survey, pursuant to section 101 (a)(5)(D) of the MMPA, 16 U.S.C. § 1371(a)(5)(D).

This consultation, opinion, and incidental take statement, were completed in accordance with ESA section 7, associated implementing regulations (50 C.F.R. §§402.01-402.16), and agency policy and guidance. This consultation was conducted by the NMFS Office of Protected Resources Endangered Species Act Interagency Cooperation Division (hereafter referred to as "we" or "our"). We also completed an Essential Fish Habitat (EFH) consultation on the proposed action in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and

Management Act (MSA; 16 U.S.C. § 1801 et seq.) and implementing regulations at 50 CFR Part 600. Consistent with Secretarial Order (#3206)*: American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act*, we conducted outreach with affected tribes in the action area to discuss how the proposed action may impact tribal trust resources.

This document represents the NMFS ESA Interagency Cooperation Division's opinion on the effects of the proposed actions on endangered and threatened marine mammals, sea turtles, and fishes and designated and proposed critical habitat for those species. A complete record of this consultation is on file at the NMFS Office of Protected Resources in Silver Spring, Maryland.

1.1 Background

The NSF is proposing to fund and conduct a marine seismic survey for scientific research purposes and data collection in the Cascadia Subduction Zone in the Northeast Pacific Ocean off the coasts of Oregon, Washington, and Vancouver Island, Canada in the summer of 2021. The National Science Foundation, as the research funding and action agency, has a mission to "promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…" The proposed seismic survey will collect data in support of a research proposal that has been reviewed under the National Science Foundation merit review process and identified as a National Science Foundation program priority. In conjunction with this action, the NMFS Permits and Conservation Division proposes the issuance of an IHA pursuant to the MMPA requirements for incidental takes of marine mammals that could occur during the NSF seismic survey. This document represents the NMFS ESA Interagency Cooperation Division's opinion on the effects of the two proposed federal actions on threatened and endangered species, and has been prepared in accordance with section 7 of the ESA. Both the NSF and the NMFS Permits and Conservation Division have conducted similar actions in the past that have been the subject of ESA section 7 consultations. The previous opinions for NSF's seismic surveys in the vicinity of the proposed action area, which include Northeast Pacific (2012), Oregon (2017; FPR-2017-9195), and the Western Gulf of Alaska (2019; OPR-2018-00010) and the issuance of an IHA for each survey, determined that the authorized activities were not likely to jeopardize the continued existence of ESA-listed species, or result in the destruction or adverse modification of designated critical habitat.

The principal investigators worked with the NSF and L-DEO to consider potential times to carry out the proposed seismic surveys. Key factors taken into consideration included environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and sea birds), weather conditions, equipment, and optimal timing for other proposed seismic surveys using the R/V *Marcus G. Langseth*.

Due to operational delays related to the coronavirus pandemic, the NSF delayed the start of the proposed action from the summer of 2020 to May 20, 2021. Seismic activities would begin on June 1, and last for 37 days, ending on or about July 7. The change in timing for the proposed action does not change the ESA-listed species we expect to occur in the action area.

1.2 Consultation History

This opinion is based on information provided in the NSF draft environmental assessment/analysis (EA) prepared pursuant to the National Environmental Policy Act, L-DEO's MMPA IHA application, the NMFS Permits and Conservation Division's notice of a proposed IHA prepared pursuant to the MMPA, and information from previous NSF seismic surveys in the vicinity of the action area. Our communication with the NSF and NMFS Permits and Conservation Division regarding this consultation is summarized as follows:

- **October 2, 2019:** The NSF submitted a request for a species list.
- **November 8, 2019:** The NSF submitted the draft initiation package to the ESA Interagency Cooperation Division for review.
- **November 25, 2019:** The NSF submitted a revised draft EA which included additional activities left out of the original draft.
- **December 10, 2019:** The ESA Interagency Cooperation Division determined the initiation package was complete and initiated consultation with NSF.
- **January 28, 2020:** The ESA Interagency Cooperation Division, with cooperation from the NMFS West Coast Region's tribal liaison, sent notification letters to 18 tribes whose tribal trust resources may be affected by the proposed action. The purpose was to set up a webinar for the affected tribes to provide them with information on the proposed action and to request their input under Secretarial Order (#3206): *American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act*.
- **February 4, 2020:** The ESA Interagency Cooperation Division met with representatives from the headquarters' and the NMFS West Coast Region's Office of Habitat Conservation to discuss the Essential Fish Habitat (EFH) consultation for the proposed action.
- **March 18, 2020:** The Permits Division submitted their initiation package to the ESA Interagency Cooperation Division for review. The ESA Interagency Cooperation Division reviewed the package, determined it was complete, and initiated consultation on the same date.
- **April 10, 2020:** The NSF informed the ESA Interagency Cooperation Division that, due to complications arising from the coronavirus pandemic, the proposed action would be delayed to July 1, 2020.
- **May 29, 2020:** The NSF informed the ESA Interagency Cooperation Division and the Permits Division that the proposed action would be further delayed to the summer of 2021 due to logistical concerns arising from the coronavirus pandemic. The NSF stated they would provide additional details about the timing and any changes to the proposed survey lines as those details became available. The consultation was placed on hold.
- **January 2021:** The NSF confirmed the rescheduled dates for the proposed action. The proposed action will take place starting on May 20, 2021, with seismic activities to begin

on June 1, 2021. The ESA Interagency Cooperation Division and the Permits Division resumed work on the ESA section 7 consultation and MMPA IHA, respectively, following the notification by the NSF.

- **February 5, 2021:** The ESA Interagency Cooperation Division sent notice to each of the 18 tribes to inform them of the proposed action's new start date, and to invite them to a rescheduled informational webinar on the proposed action.
- **February 17, 2021:** The ESA Interagency Cooperation Division held an informational webinar for representatives from concerned tribes about the proposed action. In attendance were:
    - Representatives from the Makah, Quinault, and Quileute Tribes
    - Amilee Wilson, NMFS West Coast Region Tribal Liaison
    - Jolie Harrison and Amy Fowler, NMFS Permits Division
    - Cathy Tortorici and Colette Cairns, NMFS ESA Interagency Cooperation Division
    - George Galasso and Katie Wrubel, NOAA Olympic Coast National Marine Sanctuary
    - Holly Smith, National Science Foundation.
- **March 3, 2021:** Makah Tribal Councilman Timothy Greene sent a letter to the ESA Interagency Cooperation Division recommending actions NMFS and NSF could take to mitigate the effects of the proposed action to tribal trust resources.
- **March 19, 2021:** The West Coast Region Tribal Liaison sent responses to several questions posed by attendees during the February 17 webinar. These responses were developed in cooperation with the NSF and the ESA Interagency Cooperation Division. Also on this date, the ESA Interagency Cooperation Division met with biologists from the West Coast Region Habitat Conservation Division to discuss the EFH consultation.
- **March 31, 2021:** The West Coast Region Habitat Conservation Division completed the EFH consultation and provided it to the ESA Interagency Cooperation Division for incorporation in the ESA consultation document.
- **April 6, 2021**: NOAA held a fisheries coordination meeting with representatives from the Makah, Quinault, and Quileute Tribes to discuss coordinating notification to the Tribes during the NSF's action.
- **April 21, 2021:** The NMFS Office of Protected Resources responded to Councilman Greene with a letter describing our response to his recommendations. Our response detailed how the recommendations were incorporated into the proposed IHA.

2 The Assessment Framework

Section 7(a)(2) of the ESA requires Federal agencies, in consultation with NMFS, to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species; or adversely modify or destroy their designated critical habitat.

"Jeopardize the continued existence of" means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of an ESA-listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 C.F.R. §402.02).

"Destruction or adverse modification" means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species (50 C.F.R. §402.02).

An ESA section 7 assessment involves the following steps:

Description of the Proposed Action (Section 3): We describe the proposed action and those aspects (or stressors) of the proposed action that may have effects on the physical, chemical, and biotic environment. This section also includes the avoidance and minimization measures that have been incorporated into the project to reduce the effects to ESA-listed species.

Action Area (Section 4): We describe the action area with the spatial extent of the stressors from the action.

Endangered Species Act-Listed Species and Proposed or Designated Critical Habitat Present in the Action Area (Section 5): We identify the ESA-listed species and designated critical habitat that are likely to co-occur with the stressors produced by the proposed action in space and time.

Potential Stressors (Section 6): We identify the stressors that could occur as a result of the proposed action and affect ESA-listed species and designated critical habitat. We include a section (Section 7.1) for stressors that are not likely to adversely affect the species that are analyzed further in this opinion.

We also identify those *Species and Critical Habitat Not Likely to be Adversely Affected* (Section 7) and detail our effects analysis for these species and critical habitats (Sections 7.2 and 7.2.5).

Status of Species and Critical Habitat Likely to be Adversely Affected (Section 8): We examine the status of each species and critical habitat that may be adversely affected by the proposed action.

*Environmental Baseline (*Section 9): We describe the environmental baseline in the action area as the condition of the listed species and designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. The consequences to listed species from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline.

Effects of the Action (Section 10): Effects of the action are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the proposed action and is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action. These are broken into analyses of exposure, response, and risk, as described below for the species that are likely to be adversely affected by the action.

Exposure, Response, and Risk Analyses (Section 10.2, 10.2.2, and 10.3): We identify the number, age (or life stage), and sex of ESA-listed individuals that are likely to be exposed to the stressors and the populations or subpopulations to which those individuals belong. We also identify the unit(s) of designated critical habitat that are likely to be exposed. This is our exposure analysis. We evaluate the available evidence to determine how individuals of those ESA-listed species are likely to respond given their probable exposure. We also consider how designated critical habitat in terms of changes in function. This is our response analysis (Section 10.2.2). We assess the consequences of these responses of individuals that are likely to be exposed to the populations those individuals represent, and the species those populations comprise. We also assess the consequences of responses of critical habitat to the critical habitat unit(s) and how changes in function may affect the conservation value of designated critical habitat. This is our risk analysis (Section 10.3).

Cumulative Effects (Section 11): Cumulative effects are the effects to ESA-listed species and designated critical habitat of future state or private activities that are reasonably certain to occur within the action area (50 C.F.R. §402.02). Effects from future Federal actions that are unrelated to the proposed action are not considered because they require separate ESA section 7 compliance.

Integration and Synthesis (Section 12): With full consideration of the status of the species and the designated critical habitat, we consider the effects of the action within the action area on populations or subpopulations and on essential habitat features when added to the environmental baseline and the cumulative effects to determine whether the action could reasonably be expected to:

- Reduce appreciably the likelihood of survival and recovery of ESA-listed species in the wild by reducing its numbers, reproduction, or distribution, and state our conclusion as to whether the action is likely to jeopardize the continued existence of such species; and/or
- Appreciably diminish the value of designated critical habitat for the conservation of an ESA-listed species, and state our conclusion as to whether the action is likely to destroy or adversely modify designated critical habitat.

The results of our jeopardy and destruction and adverse modification analyses are summarized in the *Conclusion* (Section 13). If, in completing the last step in the analysis, we determine that the action under consultation is likely to jeopardize the continued existence of ESA-listed species or destroy or adversely modify designated critical habitat, then we must identify Reasonable and Prudent Alternative(s) to the action, if any, or indicate that to the best of our knowledge there are no reasonable and prudent alternatives (see 50 C.F.R. §402.14(h)(3)).

An *Incidental Take Statement* (Section 14) is included for those actions for which take of ESA-listed species is reasonably certain to occur in keeping with the revisions to the regulations specific to ITSs (80 FR 26832, May 11, 2015: ITS rule). The ITS specifies the impact of the take, reasonable and prudent measures to minimize the impact of the take, and terms and conditions to implement the reasonable and prudent measures (ESA section 7 (b)(4); 50 C.F.R. §402.14(i)).

We also provide discretionary *Conservation Recommendations* (Section 15) that may be implemented by action agency (50 C.F.R. §402.14(j)). Finally, we identify the circumstances in which *Reinitiation of Consultation* (Section 16) is required (50 C.F.R. §402.16). In Section 17, we present the Magnuson-Stevens Fishery Conservation and Management Act EFH consultation response.

2.1 Evidence Available for the Consultation

To comply with our obligation to use the best scientific and commercial data available, we collected information identified through searches of Google Scholar and literature cited sections of peer reviewed articles, species listing documentation, and reports published by government and private entities. This opinion is based on our review and analysis of various information sources, including:

- Information submitted by the NSF and the Permits Division;
- Government reports (including NMFS biological opinions and stock assessment reports);
- NOAA technical memos; and
- Peer-reviewed scientific literature.

These resources were used to identify information relevant to the potential stressors and responses of ESA-listed species and designated critical habitat under NMFS' jurisdiction that may be affected by the proposed action to draw conclusions on risks the action may pose to the continued existence of these species and the value of designated critical habitat for the conservation of ESA-listed species.

3 Description of the Proposed Action

"Action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by federal agencies (50 C.F.R. §402.02).

Two proposed Federal actions were evaluated in this consultation. The first is the National Science Foundation's (along with researchers from the L-DEO of Columbia University, the Woods Hole Oceanographic Institution, and the University of Texas at Austin's Institute for Geophysics) proposal to sponsor and conduct a high-energy marine seismic survey on the R/V

Marcus G. Langseth in the Northeast Pacific Ocean over the Cascadia Subduction Zone in the summer (June and July) of 2021, with preparation for the survey beginning on or about May 20, 2021. The R/V *Marcus G. Langseth* is operated by the L-DEO of Columbia University under an existing cooperative agreement. The principal investigators are Drs. S. Carbotte (L-DEO), P. Canales (Woods Hole Oceanographic Institution), and S. Han (University of Texas at Austin's Institute for Geophysics). Researchers from the U.S. Geological Survey, Dalhousie University, and Simon Fraser University will also be assisting the principal investigators. The second is NMFS Permits and Conservation Division's issuance of an IHA authorizing non-lethal MMPA "takes" by Level A and B harassment pursuant to section 101(a)(5)(D) of the MMPA for the National Science Foundation's high-energy marine seismic survey in the Northeast Pacific Ocean.

The proposed NSF action includes a two-dimensional high-energy seismic survey in the Exclusive Economic Zones of the U.S and Canada, including in U.S. state waters and the Territorial Waters of Canada. The proposed survey will focus on the Cascadia Subduction Zone. The acquired data will be used to characterize: 1) the deformation and topography of the incoming plate; 2) the depth, topography, and reflectivity of the megathrust; 3) sediment properties and amount of sediment subduction; and 4) the structure and evolution of the accretionary wedge, including geometry and reflectivity of fault networks, and how these properties vary along strike, spanning the full length of the margin and down dip across what may be the full width of the seismogenic zone at Cascadia. The data will be processed to pre-stack depth migration using state-of-the art seismic processing techniques and would be made openly available to the community, providing a high-quality data set illuminating the regional subsurface architecture all along the Cascadia Subduction Zone.

Thus, the survey will provide data necessary to examine the depth, geometry, and physical properties of the seismogenic portion and updip extent of the megathrust zone between the subducting Juan de Fuca plate and the overlying accretionary wedge/North American Plate. These data would provide essential constraints for earthquake and tsunami hazard assessment in the region. The portion of the megathrust targeted for this survey is the source region for great earthquakes that occurred at Cascadia in pre-historical times, comparable in size to the Tohoku M9 earthquake in 2011; an earthquake of similar size is possible at Cascadia within the next century.

The information presented here is based primarily on the draft EA, IHA application, and *Federal Register* notice of the proposed IHA provided by the NSF and NMFS Permits and Conservation Division as part of their initiation packages.

3.1 National Science Foundation's and Lamont-Doherty Earth Observatory of Columbia University's Proposed Activities

The National Science Foundation proposes to fund and conduct a seismic survey in the Northeast Pacific Ocean on the Research Vessel (R/V) *Marcus G. Langseth* (operated by the L-DEO). A 36-airgun array will be deployed as an energy source. A multi-beam echosounder, sub-bottom profiler, and acoustic Doppler current profiler will be operated during the survey, and ocean-bottom seismometers and ocean-bottom nodes will collect data. A remotely operated vehicle (ROV) will be used to retrieve the ocean-bottom nodes.

3.1.1 Seismic Survey Overview

The survey will take place in the U.S. Exclusive Economic Zone (370.4 kilometers [200 nautical miles]), and in state waters of Oregon and Washington, in waters depths of approximately 60 to 4,400 meters (197 to 14,436 feet). The survey will also take place in the Exclusive Economic Zone of Canada, and the territorial seas of Canada (off the coast of British Columbia).

All planned seismic data acquisition activities will be conducted by the National Science Foundation and researchers, with onboard assistance by technical staff and the marine operations group. The research vessel will be self-contained, and the scientific party and crew will live aboard the vessel for the entire seismic survey.

The R/V *Marcus G. Langseth* is tentatively planned to depart port on May 20, 2021, and return to port in July 2021. The first part of the action involves a support vessel deploying ocean bottom seismometers and nodes that will be used to record the seismic data. Ocean bottom seismometers are deployed using a boom over the side of the vessel, while ocean bottom nodes are deployed using a ROV. After that is completed, the seismic survey activities will begin on June 1st. The seismic survey will consist of a total of approximately 40 days, including approximately 37 days of airgun array operations, approximately two days of equipment deployment and retrieval, and approximately one day of transit. The R/V *Marcus G. Langseth* will depart and return to port in Astoria, Oregon. Some minor deviation from the dates is possible, depending on logistics and weather.

The National Science Foundation will use conventional seismic survey methodology and the procedures will be similar to those used during previous seismic surveys. Seismic survey protocols generally involve a predetermined set of tracklines. The seismic acquisition or sound source vessel travels down a linear trackline for some distance until a line of data is acquired, then turns and acquires data on a different trackline.

A maximum of approximately 6,540 kilometers (3,531 nautical miles) of tracklines will be surveyed in the Northeast Pacific Ocean (see Figure 1). The location of the tracklines may shift from what is depicted in Figure 1 depending on factors such as mechanical issues, poor data quality, weather, etc.

There will be additional airgun array operations in the seismic survey area associated with turns, airgun array testing, and repeat coverage of any areas where initial data quality is considered sub-standard by the project scientists. A section of a trackline may need to be repeated when data quality is poor or missing due to equipment failure (e.g., airgun array or towed hydrophone streamer problems, data acquisition system issues, research vessel issues) or shut-downs or ramp-ups for protected species.

3.1.2 Vessel Specifications

The seismic survey will involve one source vessel, the U.S.-flagged R/V *Marcus G. Langseth*. The R/V *Marcus G. Langseth* is owned by the National Science Foundation and operated by Columbia University's L-DEO under an existing Cooperative Agreement. The R/V *Marcus G. Langseth* has a length of 72 meters (235 feet), a beam of 17 meters (56 feet), and a maximum draft of 5.9 meters (19.4 feet). It is 2,842 gross tons. Its propulsion system consists of two diesel Bergen BRG-6 engines, each producing 3,550 horsepower, and an 800 horsepower bowthruster. The R/V *Marcus G. Langseth*'s design is that of a seismic research vessel, with a particularly quiet propulsion system to avoid interference with the seismic signals. The operating speed during seismic data acquisition is typically approximately 8 kilometers per hour (4.3 to 4.5 knots). During the two-dimensional seismic survey, the vessel speed will be approximately 7.8 kilometers per hour (4.2 knots) and approximately 8.3 kilometers per hour (4.5 knots) during the three-dimensional seismic survey. When not towing seismic survey gear, the R/V *Marcus G. Langseth* typically cruises at 18.5 kilometers per hour (10 knots) and has a range of approximately 13,500 kilometers (7,289.4 nautical miles). No chase vessel will be used during seismic survey activities. The R/V *Marcus G. Langseth* will also serve as the platform from which vessel-based protected species observers (PSOs) (acoustic and visual) will listen and watch for animals (e.g., marine mammals and sea turtles).

The proposed seismic survey will also use a second vessel, the U.S.-flagged R/V *Oceanus*, to deploy the ocean-bottom seismometers and ocean-bottom nodes. The R/V *Oceanus* is owned by the National Science Foundation, and operated by the Oregon State University. R/V *Oceanus* has a length of 54 meters (177 feet), a beam of 10 meters (33 feet), and a draft of 5.3 meters (17.4 feet). Its gross tonnage is 261. The ship is powered by one electromotive diesel engine, producing 3,000 horsepower, which drives the single screw propeller. The vessel also has a 350 horsepower bowthruster. The cruising speed is 20 kilometers per hour, the endurance is 30 days, and the range is approximately 13,000 kilometers.

3.1.3 Airgun Array and Acoustic Receivers' Description

The energy source for the seismic survey was chosen by the National Science Foundation to be the lowest practical to meet the scientific objectives.

During the seismic survey, the R/V *Marcus G. Langseth* will deploy an airgun array (i.e., a certain number of airguns of varying sizes in a certain arrangement) as an energy source. An airgun is a device used to emit acoustic energy pulses downward through the water column and into the seafloor, and generally consists of a steel cylinder that is charged with high-pressure air. Release of the compressed air into the water column generates a signal that reflects (or refracts) off the seafloor and/or sub-surface layers having acoustic impedance contrast. When fired, a brief (approximately 0.1 second) pulse of sound is emitted by all airguns nearly simultaneously. The airguns are silent during the intervening periods with the array typically fired on a fixed distance (or shot point) interval. The return signal is recorded by a listening device (e.g., receiving system) and later analyzed with computer interpretation and mapping systems used to depict the sub-surface. In the proposed action, the receiving system will consist of the towed hydrophone array, and the ocean bottom seismometers and nodes.

The R/V *Marcus G. Langseth* will deploy a 15-kilometer towed hydrophone streamer and an airgun array to conduct the two-dimensional multi-channel seismic survey. Ocean bottom seismometers and ocean bottom nodes would be deployed by a second vessel, the R/V *Oceanus*, and retrieved by a ROV. The ocean bottom seismometers and ocean bottom nodes would receive and store the returning acoustic signals; data will be analyzed later after the devices are retrieved.

The airgun array for the two-dimensional seismic survey will consist of 36 Bolt airguns (plus four spares) with a total discharge volume of 108,154.6 cubic centimeters (6,600 cubic inches [in^3]) (Table 1). The airguns will be configured as four identical linear arrays or "strings". The four airgun strings will be towed behind the R/V *Marcus G. Langseth* and will be distributed across an area approximately 24 meters (78.7 feet) by 16 meters (52.5 feet). The shot interval will be approximately 16 to 17 seconds (approximately every 37.5 meters [123 feet]). The firing pressure of the airgun array will be approximately 1,900 pounds per square inch (psi) (plus or minus 100 psi). The four airgun strings will be towed approximately 30 meters (98 feet) behind the vessel at a tow depth of 12 meters (39.4 feet). Other source array specifications such as source output (underwater decibels referenced to one micropascal at one meter [root mean squared; dB re 1μPa-m]), pulse duration, and dominant frequency components in Table 1.

It is expected that the airgun array will be active 24 hours per day during the seismic survey (except for the area described in Section 3.1.5.6, Figure 2), where airgun operations will occur during daylight hours only). Airguns will operate continually during the seismic survey period except for unscheduled shut-downs.

Table 1. Source array and survey specifications for the proposed two-dimensional seismic survey over the Cascadia Subduction Zone in the Northeast Pacific Ocean.

Source array specifications	
Energy source	36 Bolt 40 to 360-in^3 air guns 4 strings
Source output (downward)-36 air gun array	Zero to peak = 258 dB re 1 μPa-m Peak to peak = 264 dB re 1 μPa-m
Air discharge volume	~ 6,600-in^3
Pulse duration	0.1 second
Shot interval	37.5 m
Dominant frequency components	2 to 188 hertz

Source array specifications	
Tow depth	12-meters
Sound source velocity (tow speed)	4.2 knots (7.8 kilometers per hour)

The receiving system will consist of a single 15-kilometer (8.1 nautical miles) long towed hydrophone streamer (for the two-dimensional seismic survey), and ocean bottom seismometers and ocean bottom nodes. Surveys in the 1980s and 1990s used much shorter streamers (2.6 to 4 kilometers long), which provided rather poor quality sources of data. The most recent NSF seismic survey of the Cascadia Subduction Zone, which took place in 2012, used an 8-kilometer hydrophone streamer. A longer hydrophone streamer, like the one proposed for this action, provides opportunities to suppress unwanted energy that interferes with imaging targets, allows for accurate measurements of seismic velocities, and provides a large amount of data redundancy for enhancing seismic images during data processing. As the airgun array is towed along the tracklines, the hydrophone streamer will receive the returning acoustic signals and transfer the data to the onboard processing system. The ocean bottom seismometers and nodes will receive and store the returning acoustic signals internally for later analysis.

During the seismic survey, the R/V *Oceanus* will deploy up to 115 ocean bottom seismometers, and up to 350 ocean bottom nodes (Figure 1). The ocean bottom seismometers and nodes would be placed along lines perpendicular to the multi-channel seismic margin survey lines (see Figure 1). The ocean bottom seismometers will be deployed in two phases: once by the R/V *Oceanus* off Oregon, prior to the start of the proposed survey, and the second deployment off Vancouver Island and Washington, so the R/V *Marcus G. Langseth* can survey the northern portion of the survey area. Sixty ocean bottom seismometers placed every 10 kilometers (6.2 miles) would be deployed off Oregon, and 55 ocean bottom seismometers placed every 500 meters (1,640.4 feet) off Washington and Vancouver Island. The ocean bottom seismometers would be recovered by the R/V *Oceanus*. Ocean bottom seismometers have a height and diameter of 1 meter, and an 80-kilogram (176.4 pound) steel anchor. Three ocean bottom seismometers deployed in the Olympic Coast National Marine Sanctuary would use 20-kilogram (44 pounds) concrete anchors.

To retrieve an ocean bottom seismometer placed on the sea floor, an acoustic release transponder (pinger) transmits a signal to the instrument at a frequency of 8 to 11 kilohertz and a response is received at a frequency of 11.5 to 13 kilohertz (operator selectable) to activate and release the instrument. The transmitting beam pattern is 55 degrees. The sound source level is approximately 93 decibels. The pulse duration is two milliseconds (±10 percent) and the pulse repetition rate is one per second (±50 microseconds). The transponder will trigger the burn-wire assembly that releases the instrument from the anchor on the sea floor and the device floats to the surface. The anchor for the ocean bottom seismometer is scuttled and left on the sea floor.

The ocean bottom nodes would be deployed in three locations off Oregon; 179 deployed off northern Oregon, 107 deployed off central Oregon, and another 64 deployed off southern

Oregon. ROVs will be involved in the deployment and retrieval of the ocean bottom nodes. Unlike ocean bottom seismometers, ocean bottom nodes are small, compact, not buoyant, and do not have an anchor-release mechanism. As such, the ocean bottom nodes would be deployed and retrieved by a ROV controlled from the R/V *Oceanus*.

The ROV would have a skid capable of holding 31 units. The skid would be lowered to 5 to 10 meters (16.4 to 32.8 feet) above the seafloor, and towed at a speed of 0.6 knots (1.1 kilometers per hour). The ROV would deploy the ocean bottom nodes from the skid one at a time.

Ocean bottom nodes would be deployed 17 days before the R/V *Marcus G. Langseth* begins the survey. The ROV would retrieve the ocean bottom nodes 3 days after the survey ends.

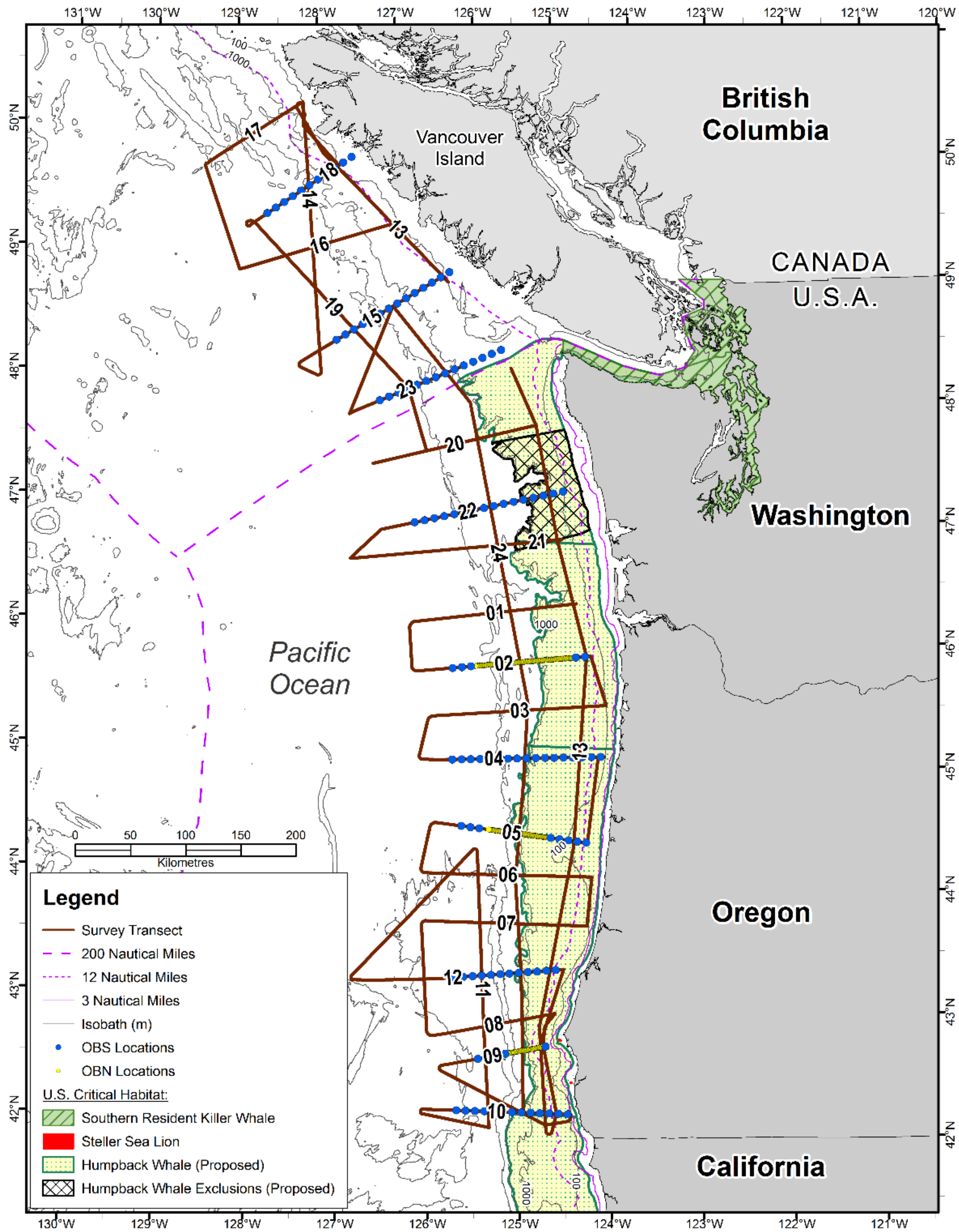

Figure 1. Action area map with locations of ocean bottom nodes and seismometers.

3.1.4 Multi-Beam Echosounder and Sub-Bottom Profiler

Along with operations of the airgun array, three additional acoustical data acquisition systems will operate during the seismic survey from the R/V *Marcus G. Langseth*. The Kongsberg EM 122 multi-beam echosounder and Knudsen Chirp 3260 sub-bottom profiler will map the ocean floor during the seismic survey. The multi-beam echosounder and sub-bottom profiler sound sources will operate continuously from the R/V *Marcus G. Langseth*, including simultaneously with the airgun array, but not during transit to and from the seismic survey area.

3.1.4.1 Multi-Beam Echosounder

The ocean floor will be mapped with the Kongsberg EM122 multi-beam echosounder. The multi-beam echosounder is a hull-mounted system operating at 10.5 to 13 (usually 12) kilohertz. The transmitting beamwidth is one or two degrees fore-aft and 150 degrees (maximum) athwartship (i.e., perpendicular to the ship's line of travel). The maximum sound source level is 242 dB re: 1 µPa-m. Each ping consists of eight (in water greater than 1,000 meters [3,281 feet]) or four (in water less than 1,000 meters [3,281 feet]) successive fan-shaped transmissions, each ensonifying a sector that extends one degree fore-aft. Continuous-wave signals increase from 2 to 15 milliseconds long in water depths up to 2,600 meters (8,530 feet) and frequency modulated chirp signals up to 100 milliseconds long are used in water greater than 2,600 meters (8,530 feet). The successive transmissions span an overall cross-track angular extent of about 150 degrees, with two millisecond gaps between the pings for successive sectors.

3.1.4.2 Sub-Bottom Profiler

The ocean floor will also be mapped with the Knudsen 3260 sub-bottom profiler. The sub-bottom profiler is normally operated to provide information about the near sea floor sedimentary features and the bottom topography that is mapped simultaneously by the multi-beam echosounder. The beam is transmitted as a 27-degree cone, which is directed downward by a 3.5-kilohertz transducer in the hull of the R/V *Marcus G. Langseth*. The nominal power output is 10 kilowatts, but the actual maximum radiated power is 3 kilowatts or 222 dB re: 1 µPa at 1 meter rms. The ping duration is up to 64 milliseconds, and the ping interval is one second. A common mode of operation is to broadcast five pulses at one-second intervals followed by a five-second pause. The sub-bottom profiler is capable of reaching depths of 10,000 meters (32,808.4 feet).

3.1.5 Proposed Conservation Measures

The National Science Foundation and L-DEO are obligated to enact mitigation measures to have their action result in the least practicable adverse impact on marine mammal species or stocks under the MMPA, which may also reduce the likelihood of adverse effects to ESA-listed marine species or adverse effects on their designated critical habitats. Monitoring is used to observe or check the progress of the mitigation over time and can also be used to ensure that any measures implemented to reduce or avoid adverse effects on ESA-listed species are successful.

The NMFS Permits and Conservation Division will require, and the National Science Foundation and L-DEO will implement, the mitigation and monitoring measures listed below. These mitigation and monitoring measures are required during the seismic survey to reduce the potential for injury to or harassment of marine mammals and sea turtles. For sea turtles, the National Science Foundation included conservation measures as part of its proposed action, namely an exclusion zone and shut down procedures. Additional details for each mitigation and monitoring measure are described in subsequent sections of this opinion, specifically:

- Proposed exclusion and buffer zones;
- Power-down procedures;

- Shut-down procedures;
- Ramp-up procedures;
- Visual monitoring by NMFS-approved PSOs;
- Passive acoustic monitoring;
- Vessel strike avoidance measures; and
- Additional mitigation measures.

Additional details on the other MMPA mitigation and monitoring measures (e.g., power-down, shut-down, and ramp-up procedures) can be found in NMFS Permits and Conservation Division *Federal Register* notice of proposed incidental harassment authorization and request for comments on proposed incidental authorization and possible renewal (85 FR 19580; April 7, 2020) and Appendix A.

3.1.5.1 Proposed Exclusion and Buffer Zones – Ensonified Area

The NMFS Permits and Conservation Division will require, and the National Science Foundation and L-DEO will implement, exclusion zones around the R/V *Marcus G. Langseth* to minimize any potential adverse effects of the sound from the airgun array on MMPA and ESA-listed sea turtles. The National Science Foundation included measures for sea turtles as part of its proposed action. The exclusion zones are areas within which occurrence of a marine mammal or sea turtle triggers a power-down or shutdown of the airgun array, to reduce exposure of marine mammals or sea turtles to sound levels expected to have adverse effects on the species. These exclusion zones are based upon modeled sound levels at various distances from the R/V *Marcus G. Langseth*, and correspond to the respective species' sound thresholds for potential injury and behavioral effects to MMPA and ESA-listed species.

Ensonified Area

The L-DEO model results are used to determine the 160 dB re: 1 μPa (rms) radius for single 40 cubic inch airgun array and 36 airgun array in shallow (less than 100 meters (328 feet) deep), intermediate (100 to 1,000 meters deep), and deep water (greater than 1,000 meters [3,280.8 feet]). This sound level was chosen because it corresponds to the distance at which Level B harassment under the MMPA occurs. Received sound levels were predicted by L-DEO's model (Diebold et al. 2010), which uses ray tracing for the direct wave traveling from the airgun array to the receiver and its associated source ghost (i.e., reflection at the air-water interface in the vicinity of the airgun array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor).

Measurements have not been reported for the single 40 cubic inch airgun array. The L-DEO model results are used to determine the 160 dB re: 1 μPa (rms) radius for the single 40 cubic inch airgun array at a tow depth of 12 meters (39.4 feet) in shallow, intermediate, and deep water. The estimated distances to the 160 dB re: 1 μPa (rms) isopleths for the single 40 cubic inch airgun array and 36-airgun array are in Table 2.

Table 2. Predicted distances to which sound levels of 160 dB re: 1 µPa (rms) for Marine Mammal Protection Act Level B harassment for impulsive sources will be received from the single 40 cubic inch airgun and the 36-airgun array in shallow, intermediate, and deep water depths for marine mammals during the proposed seismic survey in the Northeast Pacific Ocean.

Source	Volume (in³)	Water Depth (m)	Predicted Distance to Threshold (160 dB re: 1 µPa [rms]) (m)
1 Airgun	40	<100	1,041
		100 to 1,000	647
		>1,000	431
36 Airguns	6,600	<100	12,650
		100 to 1,000	9,648
		>1,000	6,733

in³=cubic inches
m=meters

The National Science Foundation will implement an exclusion zone for sea turtles. An exclusion zone of 100 meters will be used as a shutdown distance for sea turtles (see Section 10.2.2.2 below). This distance is practicable for PSOs to implement shutdowns, and is sufficiently large to prevent sea turtles from being exposed to sound levels that could result in PTSThe buffer zone will correspond to the predicted 175 dB re: 1 µPa (rms) behavioral threshold distances to which sound source levels will be received from the single airgun array and 36 airgun array in shallow, intermediate, and deep water depths described in Table 3.

Table 3. Predicted distances to which sound levels of 175 dB re: 1 µPa (rms) will be received from the single 40 cubic inch airgun and the 36-airgun array in shallow, intermediate, and deep-water depths for sea turtles during the proposed seismic survey in the Northeast Pacific Ocean.

Source	Volume (in³)	Water Depth (m)	Predicted Distance to Threshold (175 dB re: 1 µPa [rms]) (m)
1 Airgun	40	<100	170
		100 to 1,000	116

		>1,000	77
36 Airguns	6,600	<100	3,924
		100 to 1,000	2,542
		>1,000	1,864

in^3=cubic inches
m=meters
Note: The National Science Foundation and L-DEO will use a 100 meter exclusion zone in all water depths for the 36 airgun array as the shut-down distance for sea turtles.

Establishment of Proposed Exclusion and Buffer Zones

An exclusion zone is a defined area within which occurrence of an animal triggers mitigation action intended to reduce the potential for certain outcomes (e.g., auditory injury, disruption of critical behaviors). For marine mammals, PSOs will establish a default (minimum) exclusion zone with a 500 meter (1,640.4 feet) radius for visual monitoring for the 36-airgun array. The 500 meter (1,640.4 feet) exclusion zone will be based on the radial distance from any element of the airgun array (rather than being based on the center of the airgun array or around the vessel itself). With certain exceptions (described below), if a marine mammal appears within, enters, or appears on course to enter this zone, the airgun array will be powered-down or shut-down, depending on the circumstance. As stated earlier, for sea turtles, NSF will established an exclusion zone of 100 meters (328 feet), with the buffer zone corresponding to the distance to the 175 dB threshold.

The buffer zone means an area beyond the exclusion zone to be monitored for the presence of marine mammals and sea turtles that may enter the exclusion zone. The buffer zone encompasses the area at and below the sea surface from the edge of the zero to 100-meter (zero to 328 feet; for sea turtles), zero to 500-meter (zero to 1,640.4 feet; for marine mammals) exclusion zone, out to a radius of 1,000 meters (3,280.8 feet) from the edges of the airgun array (500 to 1,000 meters [1,640.4 to 3,280.8 feet]).

The 500 meter (1,640.4 feet) exclusion zone for marine mammals is intended to be precautionary in the sense that it will be expected to contain sound exceeding the injury criteria for all cetacean hearing groups (based on the dual criteria of the cumulative sound exposure level (SEL_{cum}) and peak sound pressure level (SPL)), while also providing a consistent, reasonably observable zone within which PSOs will typically be able to conduct effective observations. Additionally, a 500 meter (1,640.4 feet) exclusion zone is expected to minimize the likelihood that marine mammals will be exposed to levels likely to result in more severe behavioral responses. Although significantly greater distances may be observed from an elevated platform under good conditions, the NMFS Permits and Conservation Division believes that 500 meters (1,640.4 feet) is likely regularly attainable for PSOs using the naked eye during typical conditions.

The National Science Foundation's draft environmental analysis and L-DEO's incidental harassment authorization application have a detailed description of the modeling for the R/V

Marcus G. Langseth's airgun arrays, as well as the resulting isopleths to thresholds for the various marine mammal hearing groups and sea turtles (Tables 2-3). Predicted distances to MMPA Level A harassment isopleths, which vary based on marine mammal hearing groups, were calculated based on modeling performed by L-DEO using the NUCLEUS software program and the NMFS User Spreadsheet (https://www.fisheries.noaa.gov/action/user-manual-optional-spreadsheet-tool-2018-acoustic-technical-guidance; Table 4).

Table 4. Predicted distances to permanent threshold shift thresholds for impulsive sources for various marine mammal hearing groups and sea turtles that could be received from the single airgun as well as the 36-airgun arrays during the proposed seismic survey in the Northeast Pacific Ocean.

Threshold	Low Frequency Cetaceans (m)	Mid Frequency Cetaceans (m)	High Frequency Cetaceans (m)	Phocid Pinnipeds (m)	Otariid Pinnipeds (m)	Sea Turtles (m)
Source – 1 Airgun						
SEL_{cum}	0.5	0	0	0	0	0
Peak SPL_{flat}	1.76	0.51	12.5	1.98	0.4	0
Source – 36 Airgun Array						
SEL_{cum}	426.9	0	1.3	13.9	0	20.5
Peak SPL_{flat}	38.9	13.6	268.3	43.7	10.6	10.6

m=meters

3.1.5.2 Shut-Down and Power-Down Procedures

The shutdown of the airgun array requires the immediate deactivation of all individual elements of the airgun array while a power-down of the airgun array requires the immediate deactivation of all individual elements of the airgun array except the single 40 cubic inch airgun. Any protected species observer on duty will have the authority to delay the start of seismic survey activities or to call for shutdown or power-down of the airgun array if a marine mammal or sea turtle is detected within the applicable exclusion zone. The operator must also establish and maintain clear lines of communication directly between PSOs on duty and crew controlling the airgun array to ensure that shutdown and power-down commands are conveyed swiftly while allowing PSOs to maintain watch. When both visual and acoustic PSOs are on duty, all detections will be immediately communicated to the remainder of the on-duty protected species observer team for potential verification of visual observations by the acoustic protected species observer or of acoustic detections by visual PSOs. When the airgun array is active (i.e., anytime one or more airgun is active, including during ramp-up and power-down) and (1) a marine mammal appears within or enters the applicable exclusion zone and/or (2) a marine mammal (other than delphinds) is detected acoustically and localized within the applicable exclusion zone, the airgun array will be shut-down. When shutdown is called for by a protected species observer, the airgun array will be immediately deactivated and any dispute resolved only following deactivation. Additionally, shut-down will occur whenever passive acoustic monitoring alone (without visual sighting), confirms presence of marine mammal(s) or sea turtle(s) in the exclusion zone. If the acoustic protected species observer cannot confirm presence within the exclusion zone, visual PSOs will be notified but shutdown is not required.

Following a shutdown, the airgun array activity will not resume until the animal has cleared the exclusion zone – the 500 meter (1,640.4 feet) exclusion zone in the case of marine mammals or 100-meter exclusion zone in the case of sea turtles. For marine mammals, the animal will be considered to have cleared the 500 meter exclusion zone if it is visually observed to have departed the 500 meter exclusion zone, or it has not been seen within the 500 meter exclusion zone, or if has not been seen within the 500 meter exclusion zone for 15 minutes in the case of small odontocetes and pinnipeds, or 30 minutes in the case of mysticetes and large odontocetes, including sperm whales. For sea turtles, the animal is considered to have cleared the 100-meter exclusion zone if it is visually observed to have departed the 100-meter exclusion zone, or it has not been seen in the 100-meter exclusion zone for 15 minutes.

Power-down conditions will be maintained (except for delphinids for which shut-down is waived) until marine mammals are no longer observed within the 500 meter exclusion zone, or sea turtles are no longer observed within the 100 meter exclusion zone, following which full-power operations may be resumed without ramp-up.

A large body of anecdotal evidence indicates that small delphinoids commonly approach vessels and/or towed airgun arrays during active sound production for purposes of bow riding, with no apparent effect observed in those delphinoids (Barkaszi et al. 2012b). The potential for increased shut-downs resulting from such a measure will require the R/V *Marcus G. Langseth* to revisit the missed trackline to re-acquire data, resulting in an overall increase in the total sound energy input to the marine environment and an increase in the total duration over which the seismic survey activities is active in a given area. Although other mid-frequency hearing specialists (e.g., large delphinoids) are no more likely to incur auditory injury than are small delphinoids, they are much less likely to approach vessels. Therefore, retaining a power-down and/or shut-down requirement for large delphinoids will not have similar impacts in terms of either practicability for the applicant or corollary increase in sound energy output and time on the water. The NMFS Permits and Conservation Division anticipates some benefit for a power-down and/or shut-down requirement for large delphinoids in that it simplifies somewhat the total range of decision-making for PSOs and may preclude any potential for physiological effects other than to the auditory system, as well as some more severe behavioral reactions for any such animals in close proximity to the sound source vessel.

Visual PSOs will use best professional judgement in making the decision to call for a shut-down if there is uncertainty regarding identification (i.e., whether the observed marine mammal[s] belongs to one of the delphinid genera for which shut-down is waived or one of the species with a larger exclusion zone). If PSOs observe any behaviors in a small delphinid for which shutdown is waived that indicate an adverse reaction, then power-down will be initiated immediately.

In addition to the shutdown and power-down procedures described above, the NMFS Permits and Conservation Division's MMPA incidental harassment authorization will require shutdowns if:

- Any ecotype of killer whale is visually observed at any distance.
- A killer whale is acoustically detected during passive acoustic monitoring.
- Any large whale (defined as a sperm whale or any mysticete [baleen whale]) species with a calf (defined as an animal less than two-thirds the body size of an adult observed to be in close association with an adult) is observed at any distance.
- An aggregation of six or more large whales is observed at any distance.
- A North Pacific right whale is observed at any distance.

3.1.5.3 Pre-Clearance and Ramp-Up Procedures

Ramp-up (sometimes referred to as "soft-start") means the gradual and systematic increase of emitted sound levels from an airgun array. Ramp-up begins by first activating a single airgun of the smallest volume, followed by doubling the number of active elements in stages until the full complement of an airgun array are active. Each stage will be approximately the same duration, and the total duration will not be less than approximately 20 minutes. The intent of pre-clearance observation (30 minutes) is to ensure no protected species are observed within the buffer zone prior to the beginning of ramp-up. During pre-clearance is the only time observations of protected species in the buffer zone will prevent operations (i.e., the beginning of ramp-up). The intent of ramp-up is to warn protected species of pending seismic survey activities and to allow sufficient time for those animals to leave the immediate vicinity. A ramp-up procedure, involving a step-wise increase in the number of airguns firing and total airgun array volume until all operational airguns are activated and the full volume is achieved, is required at all times as part of the activation of the airgun array. All operators must adhere to the following pre-clearance and ramp-up requirements:

- The operator must notify a designated protected species observer of the planned start of ramp-up as agreed upon with the lead protected species observer; the notification time will not be less than 60 minutes prior to the planned ramp-up in order to allow the protected species observer time to monitor the exclusion and buffer zones for 30 minutes prior to the initiation of ramp-up (pre-clearance);
- Ramp-ups will be scheduled so as to minimize the time spent with the airgun array activated prior to reaching the designated run-in;

- One of the PSOs conducting pre-clearance observations must be notified again immediately prior to initiating ramp-up procedures and the operator must receive confirmation from the protected species observer to proceed;
- Ramp-up may not be initiated if any marine mammals or sea turtle is within the applicable exclusion or buffer zone. If a marine mammal or sea turtle is observed within the applicable exclusion zone or the buffer zone during the 30 minute pre-clearance period, ramp-up may not begin until the animal(s) has been observed exiting the zones or until an additional time period has elapsed with no further sightings (15 minutes for small odontocetes and sea turtles) and 30 minutes for all other species (e.g. marine mammals).
- Ramp-up will begin by activating a single airgun array of the smallest volume in the airgun array and will continue in stages by doubling the number of active elements at the commencement of each stage, with each stage of approximately the same duration. Duration will not be less than 20 minutes. The operator must provide information to the protected species observer documenting that appropriate documenting that appropriate procedures were followed;
- PSOs must monitor the exclusion and buffer zones during ramp-up, and ramp-up must cease and the airgun array must be shutdown upon observation of a marine mammal or sea turtle within the applicable exclusion zone. Once ramp-up has begun, observations of marine mammals within the buffer zone do not require shut-down or power-down, but such observation will be communicated to the operator to prepare for the potential shut-down or power-down;
- Ramp-up may occur at times of poor visibility, including nighttime, if appropriate acoustic monitoring has occurred with no detections in the 30 minutes prior to beginning ramp-up. Airgun array activation may only occur at times of poor visibility where operational planning cannot reasonably avoid such circumstances;
- If the airgun array is shut-down for brief periods (i.e., less than 30 minutes) for reasons other than that described for shut-down and power-down (e.g., mechanical difficulty), it may be activated again without ramp-up if PSOs have maintained constant visual and/or passive acoustic monitoring and no visual or acoustic detections of marine mammals or sea turtles have occurred within the applicable exclusion zone. For any longer shutdown, pre-clearance observation and ramp-ups are required. For any shut-down at night or in periods of poor visibility (e.g., Beaufort sea state 4 or greater), ramp-up is required, but if the shut-down period was brief and constant observation was maintained, pre-clearance watch of 30 minutes is not required; and
- Testing of the airgun array involving all elements requires ramp-up. Testing limited to individual elements or strings of the airgun array does not require ramp-up but does require pre-clearance of 30 minutes.

3.1.5.4 Vessel-Based Visual Mitigation Monitoring

Visual monitoring requires the use of trained PSOs to scan the ocean surface visually for the presence of marine mammals or sea turtles. The area to be scanned visually includes primarily the exclusion zone (0 to 500 meters), but also the buffer zone. As described above, the buffer zone is an area beyond the exclusion zone to be monitored for the presence of marine mammals and sea turtles that may enter the exclusion zone. During pre-clearance monitoring (i.e., before ramp-up begins), the buffer zone also acts as an extension of the exclusion zone in that observations of marine mammals and sea turtles within the buffer zone will also prevent airgun array operations from beginning (i.e., ramp-up). Visual monitoring of the exclusion zone and adjacent waters is intended to establish and, when visual conditions allow, maintain zones around the sound source that are clear of marine mammals and sea turtles, thereby reducing or eliminating the potential for injury and minimizing the potential for more severe behavioral reactions for animals occurring close to the vessel. Visual monitoring of the buffer zone is intended to (1) provide additional protection to naïve marine mammals that may be in the area during pre-clearance; and (2) during use of the airgun array, aid in establishing and maintaining the exclusion zone by alerting the visual protected species observer and crew of marine mammals and sea turtles that are outside of, but may approach and enter, the exclusion zone.

The National Science Foundation and L-DEO must use at least five dedicated, trained, NMFS-approved PSOs. The PSOs must have no tasks other than to conduct observational effort, record observational data, and communicate with and instruct relevant vessel crew with regard to the presence of marine mammals and sea turtles and mitigation requirements. The PSO resumes shall be provided to NMFS for approval.

At least one of the visual and two of the acoustic PSOs aboard the vessel must have a minimum of 90 days at-sea experience working in those roles, respectively, during a deep penetration (i.e., high-energy) seismic survey, with no more than 18 months elapsed since the conclusion of the at-sea experience. One visual protected species observer with such experience shall be designated as the lead for the entire protected species observer team. The lead protected species observer shall serve as the primary point of contact for the vessel operator and ensure all protected species observer requirements per the MMPA incidental harassment authorization are met. To the maximum extent practicable, the experienced PSOs will be scheduled to be on duty with those PSOs with appropriate training but who have not yet gained relevant experience.

During seismic survey activities (e.g., any day on which use of the airgun array is planned to occur, and whenever the airgun array is in the water, whether activated or not), a minimum of two visual PSOs must be on duty and conducting visual observations at all times during daylight hours (i.e., from 30 minutes prior to sunrise through 30 minutes following sunset) and 30 minutes prior to and during nighttime ramp-ups of the airgun array. Visual monitoring of the exclusion and buffer zones must begin no less than 30 minutes prior to ramp-up and must continue until one hour after use of the airgun array ceases or until 30 minutes past sunset. Visual PSOs shall coordinate to ensure 360-degree visual coverage around the vessel from the most appropriate observation posts, and shall conduct visual observations using binoculars and the naked eye while free from distractions and in a consistent, systematic, and diligent manner.

The PSOs will establish and monitor the buffer and exclusion zones. The buffer and exclusion zones will be based upon the radial distance from the edges of the airgun array (rather than being based on the center of the airgun array or around the vessel itself). During use of the airgun array (i.e., anytime the airgun array is active, including ramp-up), occurrences of marine mammals and sea turtles within the buffer zone (but outside the exclusion zone) will be communicated to the operator to prepare for the potential shutdown or power-down for the airgun array.

Visual PSOs will immediately communicate all observations to the on-duty acoustic protected species observer(s), including any determination by the protected species observer regarding species identification, distance, and bearing and the degree of confidence in the determination. Any observations of marine mammals and sea turtles by crewmembers will be relayed to the protected species observer team. During good conditions (e.g., daylight hours, Beaufort sea state three or less), visual PSOs will conduct observations when the airgun array is not operating for comparison of sighting rates and behavior with and without use of the airgun array and between acquisition periods, to the maximum extent practicable. Visual PSOs may be on watch for a maximum of four consecutive hours followed by a break of at least one hour between watches and may conduct a maximum of 12 hours of observation per 24-hour period. Combined observational duties (visual and acoustic, but not at the same time) may not exceed 12 hours per 24-hour period for any individual protected species observer.

3.1.5.5 Passive Acoustic Monitoring

Passive acoustic monitoring means the use of trained personnel operators herein referred to as acoustic PSOs to operate passive acoustic monitoring equipment to acoustically detect the presence of marine mammals. Passive acoustic monitoring involves acoustically detecting marine mammals, regardless of distance from the airgun array, as localization of animals may not always be possible. Passive acoustic monitoring is intended to further support visual monitoring (during daylight hours) in maintaining an exclusion zone around the airgun array that is clear of marine mammals. In cases where visual monitoring is not effective (e.g., due to weather, nighttime), passive acoustic monitoring may be used to allow certain activities to occur, as further detailed below.

Passive acoustic monitoring will take place in addition to the visual monitoring program. Visual monitoring typically is not effective during periods of poor visibility or at night, and even with good visibility, is unable to detect marine mammals when they are below the surface or beyond visual range. Passive acoustic monitoring can be used in addition to visual observations to improve detection, identification, and localization of cetaceans. The passive acoustic monitoring will serve to alert visual PSOs (if on duty) when vocalizing cetaceans are detected. It is only useful when marine mammals call, but it can be effective either by day or night, and does not depend on good visibility. It will be monitored in real time so that the visual PSOs can be advised when cetaceans are detected.

The R/V *Marcus G. Langseth* will use a towed passive acoustic monitoring system, which must be monitored by a minimum one on-duty acoustic protected species observer beginning at least 30 minutes prior to ramp-up and at all times during use of the airgun array. Acoustic PSOs may be on watch for a maximum of four consecutive hours followed by a break of at least one hour between watches and may conduct a maximum of 12 hours of observation per 24-hour period for any individual protected species observer.

Seismic survey activities may continue for 30 minutes when the passive acoustic monitoring system malfunctions or is damaged, while the passive acoustic monitoring operator diagnoses the issue. If the diagnosis indicates that the passive acoustic monitoring system must be repaired to solve the problem, operations may continue for an additional five hours without passive acoustic monitoring during daylight hours only under the following conditions:

- Beaufort sea state is less than or equal to four;
- No marine mammals (excluding delphinids) detected solely by passive acoustic monitoring in the applicable exclusion zone in the previous two hours;
- NMFS is notified via email as soon as practicable with the time and location in which operations began occurring without an active passive acoustic monitoring system; and
- Operations with an active airgun array, but without an operating passive acoustic monitoring system, do not exceed a cumulative total of four hours in any 24-hour period.

The passive acoustic monitoring system will be used to implement shutdown requirements if killer whale vocalizations are detected, regardless of localization.

3.1.5.6 Operational Restrictions

While the R/V *Marcus G. Langseth* is surveying in waters 200 meters deep or less along the coast between Tillamook Head, Oregon and Barkley Sound, British Columbia (between latitudes 45.9460903° N and 48.780291° N), and within the boundaries of Olympic Coast National Marine Sanctuary, in the areas noted in Figure 2, survey operations will occur in daylight hours only (i.e., from 30 minutes prior to sunrise through 30 minutes following sunset). This is to ensure that PSOs are able to visually observe the entire 500-meter exclusion zone and beyond to implement shutdown procedures for species or situations with additional shutdown requirements outlined above (e.g., killer whale of any ecotype, aggregation of six or more large whales, and large whale with a calf). This particular area was selected because of the predicted density of Southern Resident killer whales in the coastal waters off Washington (see 9.3.1.1 for more details). In other locations throughout the survey area, airgun operations may occur 24 hours per day.

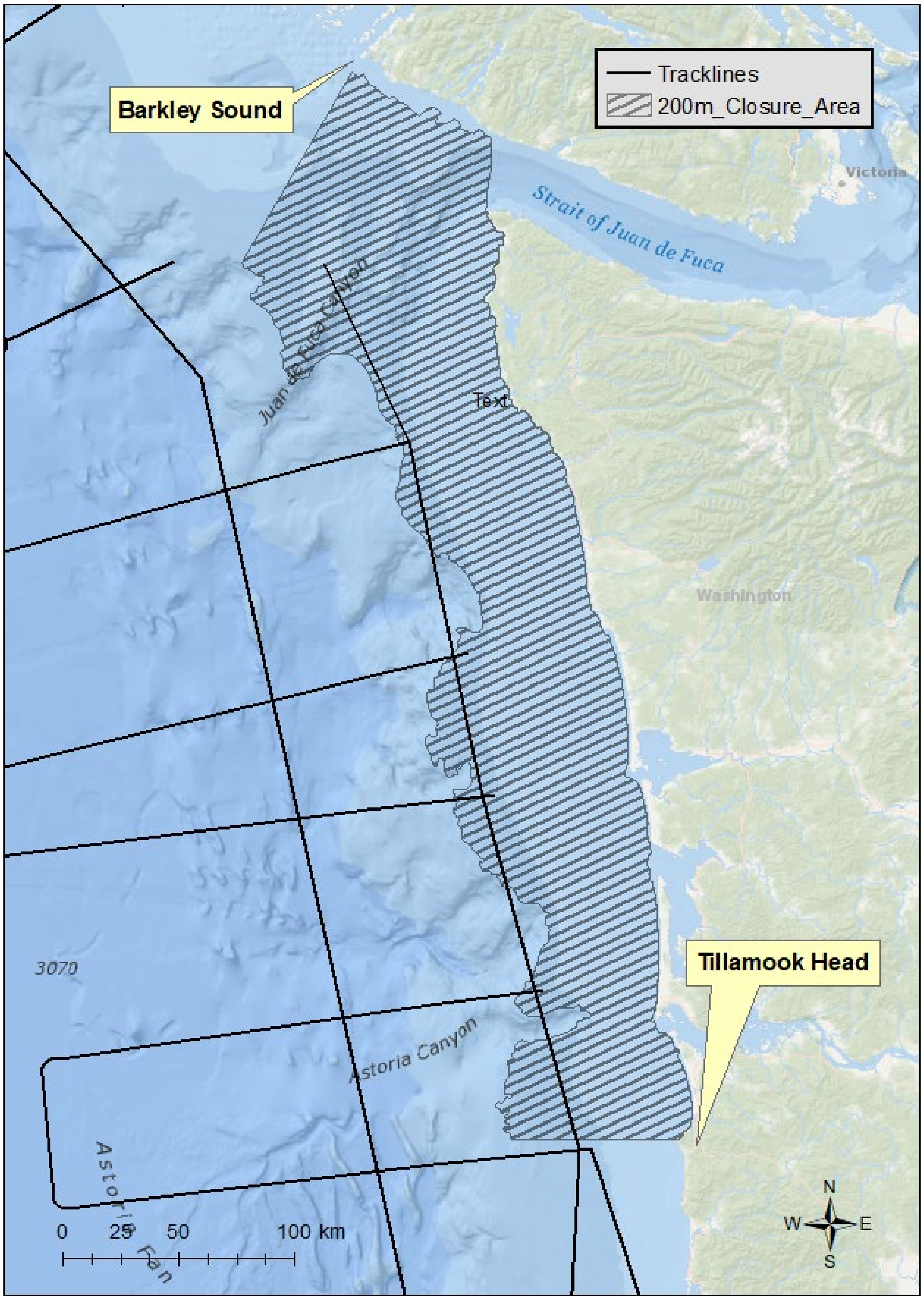

Figure 2. Map of the 200-meter depth exclusion area.

3.1.5.7 Communication

The L-DEO will communicate daily with NMFS Northwest Fisheries Science Center, NMFS West Coast Region, The Whale Museum, Orca Network, Canada's Division of Fisheries and Ocean and/or other sources for near real-time reporting for the whereabouts of Southern Resident killer whales.

3.1.5.8 Vessel Strike Avoidance

Vessel strike avoidance measures are intended to minimize the potential for collisions with marine mammals and sea turtles. The vessel strike avoidance measures apply to all vessels associated with the planned seismic survey activities. NMFS Permits and Conservation Division notes that these requirements do not apply in any case where compliance will create an imminent and serious threat to a person or vessel or to the extent that a vessel is restricted in its ability to maneuver and, because of the restriction, cannot comply. These measures include the following:

- The vessel operator (R/V *Marcus G. Langseth*) and crew will maintain a vigilant watch during daylight hours for all marine mammals and sea turtles and slow down, stop, or alter the course of the vessel, as appropriate and regardless of vessel size, to avoid striking any marine mammal and sea turtle during seismic survey activities as well as transits. A single marine mammal at the surface may indicate the presence of submerged animals in the vicinity of the vessel; therefore, precautionary measures should be exercised when an animal is observed. A visual observer aboard the vessel will monitor a vessel strike avoidance zone around the vessel, to ensure the potential for vessel strike is minimized, according to the parameters stated below. Visual observers monitoring the vessel strike avoidance zone can be either third-party PSOs or crew members, but crew members responsible for these duties will be provided sufficient training to distinguish marine mammals and sea turtles from other phenomena and broadly to identify marine mammals and sea turtles to broad taxonomic group (i.e., as a large whale or other marine mammal).
- Vessel speeds must be reduced to 18.5 kilometers per hour (10 knots) or less when mother/calf pairs, pods, or large assemblages of marine mammals are observed near the vessel.
- The vessel (R/V *Marcus G. Langseth*) will maintain a minimum separation distance of 100 meter (328.1 feet) from large whales (i.e., all baleen whales and sperm whales).
- The vessel will maintain a minimum separation distance of 50 meter (164 feet) from all other marine mammals and sea turtles, with an exception made for animals that approach the vessel.
- When marine mammals are sighted while a vessel is underway, the vessel must take action as necessary to avoid violating the relevant separation distance. If marine mammals or sea turtles are sighted within the relevant separation distance, the vessel must reduce speed and shift the engine to neutral, not engaging the engines until animals are clear of the area. This recommendation does not apply to any vessel towing gear.

3.1.5.9 Location and Timing

After discussion with the L-DEO, the NSF, the Permits Division, and NMFS regional experts, the NSF agreed to revise the location of the proposed survey lines off the coast of Washington. This was done out of concerns over impacts to Southern Resident killer whales. As a result of additional discussions the NSF had with the Canada Division of Fisheries and Oceans, the NSF made other alterations to the proposed survey lines over concerns to Southern Resident killer whales in Canadian territorial waters. See Section 10.2.1.2 for a more detailed discussion.

3.2 National Marine Fisheries Service's Proposed Activities

On November 25, 2019, NMFS Permits and Conservation Division received a request from the National Science Foundation and L-DEO for an incidental harassment authorization under the MMPA to take marine mammals incidental to conducting a high-energy marine seismic survey in the Northeast Pacific Ocean over the Cascadia Subduction zone. On March 6, 2020, NMFS Permits and Conservation Division deemed the National Science Foundation and L-DEO's application for an MMPA incidental harassment authorization to be adequate and complete. The National Science Foundation and L-DEO's request is for take of a small number of 31 species of marine mammals by MMPA Level A and Level B harassment. Neither the National Science Foundation, L-DEO, nor NMFS Permits and Conservation Division expects serious injury or mortality to result from the proposed activities; therefore, an MMPA incidental harassment authorization is appropriate. The planned seismic survey is not expected to exceed one year; hence, the NMFS Permits and Conservation Division does not expect subsequent MMPA incidental harassment authorizations will be issued for this proposed action. The incidental harassment authorization will be valid for a period of one year from the date of issuance. The NMFS Permits and Conservation Division proposes to issue the incidental harassment authorization after April 2021, so that the National Science Foundation and L-DEO's will have the incidental harassment authorization prior to the start of the proposed activities. Because the National Science Foundation and L-DEO have tentatively scheduled the proposed activities to begin on May 20, 2021 (seismic activities to begin on June 1, 2021), they have requested that the incidental harassment authorization be issued by early May 2021.

3.2.1 National Marine Fisheries Service's Proposed Incidental Harassment Authorization

The NMFS Permits and Conservation Division is proposing to issue an incidental harassment authorization authorizing non-lethal "takes" by MMPA Level A and Level B harassment of marine mammals incidental to the planned seismic survey. The incidental harassment authorization will be valid for a period of one year from the date of issuance. The incidental harassment authorization will authorize the incidental harassment of the following threatened and endangered marine mammal species: Southern Resident killer whale (*Orcinus orca*), blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), Central America distinct population segment (DPS) of humpback whale (*Megaptera novaeangliae*), Mexico DPS of humpback whale, sei whale (*Balaenoptera borealis*), sperm whale (*Physeter macrocephalus*), and Guadalupe fur seal (*Arctocephalus townsendi*). The proposed incidental harassment authorization identifies requirements that the National Science Foundation must comply with as part of its authorization.

On April 7, 2020, NMFS Permits and Conservation published a notice of proposed incidental harassment authorization and request for comments on proposed incidental harassment authorization and possible renewal in the *Federal Register* (85 FR 19580). The public comment period closed on May 7, 2020. Appendix A contains the final incidental harassment authorization.

3.2.2 National Marine Fisheries Service's Revisions to Proposed Incidental Harassment Authorization

The NMFS Permits and Conservation Division made revisions to the proposed incidental harassment authorization since the notice was published in the *Federal Register* on April 7, 2020 (85 FR 19580). The revisions are based on public comments received from the Marine Mammal Commission and others. The revisions to the proposed incidental harassment authorization include modifications to the incidental take estimates of marine mammals, operational restrictions, mitigation measures, and survey lines. The proposed action was updated to reflect these changes.

4 Action Area

Action area means all areas affected directly, or indirectly, by the Federal action, and not just the immediate area involved in the action (50 C.F.R. §402.02).

The proposed action will take place in the Northeast Pacific Ocean between approximately 42° to 51° North, and 124° to 130° West. The proposed action will take place within the exclusive economic zones of U.S. and Canada, and the Canadian Internal Waters of Vancouver Island, British Columbia.

The survey will occur in the U.S. Exclusive Economic Zone (370.4 kilometers [200 nautical miles]) off Oregon and Washington in waters depths of approximately 60 to 4,400 meters (197 to 14,436 feet). The survey will also take place in the Exclusive Economic Zone of Canada, and the territorial seas of Canada (off the coast of British Columbia). The nearest trackline to shore would be about 12 kilometers off the coast of Oregon; the furthest trackline would be about 200 kilometers from shore. The state of Washington's jurisdictional waters are 3 nautical miles from shore (5.6 kilometers), and the state of Oregon claims 3 geographical miles (5.6 kilometers) from shore as its jurisdictional waters. The survey tracklines themselves are outside the state jurisdictional waters, and are far enough offshore that the ensonified area created by the airgun blasts would not extend into the state waters of Oregon or Washington.

Under Canadian law, its maritime zones are categorized as Canadian Internal Waters, and the Exclusive Economic Zone. Like the U.S., the Exclusive Economic Zone in Canada is 200 nautical miles (370.4 kilometers; Oceans Act [S.C. 1996, c. 31, Part I, 13(1)]). Canadian Internal Waters are the waters "on the landward side of the baselines of the territorial sea of Canada", with territorial seas defined as 12 nautical miles (22 kilometers; Oceans Act [S.C. 1996, c. 31]). Portions of the proposed survey tracklines in Canada will take place in the territorial seas of Canada, as well as in the Canadian Exclusive Economic Zone. About 3.6 percent of the transect lines (234 kilometers) would take place in Canadian Internal Waters.

Representative tracklines for the proposed action are shown in Figure 3. The representative tracklines shown in Figure 3 have a total length of approximately 6,540 kilometers. Some minor deviation of the tracklines, including the order of operations, may occur for reasons such as poor data quality, inclement weather, or mechanical issues with the equipment and/or research vessel. The tracklines can occur anywhere within the coordinates noted in Figure 3.

The action area includes the survey tracklines, the transit for turns, and the area ensonified by the airgun array during the seismic survey. The total amount of ensonified area for the proposed seismic survey is approximately 79,582 square kilometers. Approximately 65.9 percent of the ensonified area will occur in waters greater than 1,000 meters deep (52,439 square kilometers), 23,562 square kilometers (29.6 percent) would occur in waters 1,000 to 100 meters deep, and the rest of the survey would take place in waters less than 100 meters deep (3,581 square kilometers, or 4.5 percent). The turns are the path the R/V *Marcus G. Langseth* will take as it finishes one survey trackline and transits to another; the airgun array will be active during turns. The action area will also include the area covered by the R/V *Marcus G. Langseth* while transiting from its port to the seismic survey area, and its return at the conclusion of the seismic survey. The R/V *Marcus G. Langseth* and *Oceanus* are expected to leave the port of Newport, Oregon, and return to the port of Seattle, Washington. The port locations may be subject to change.

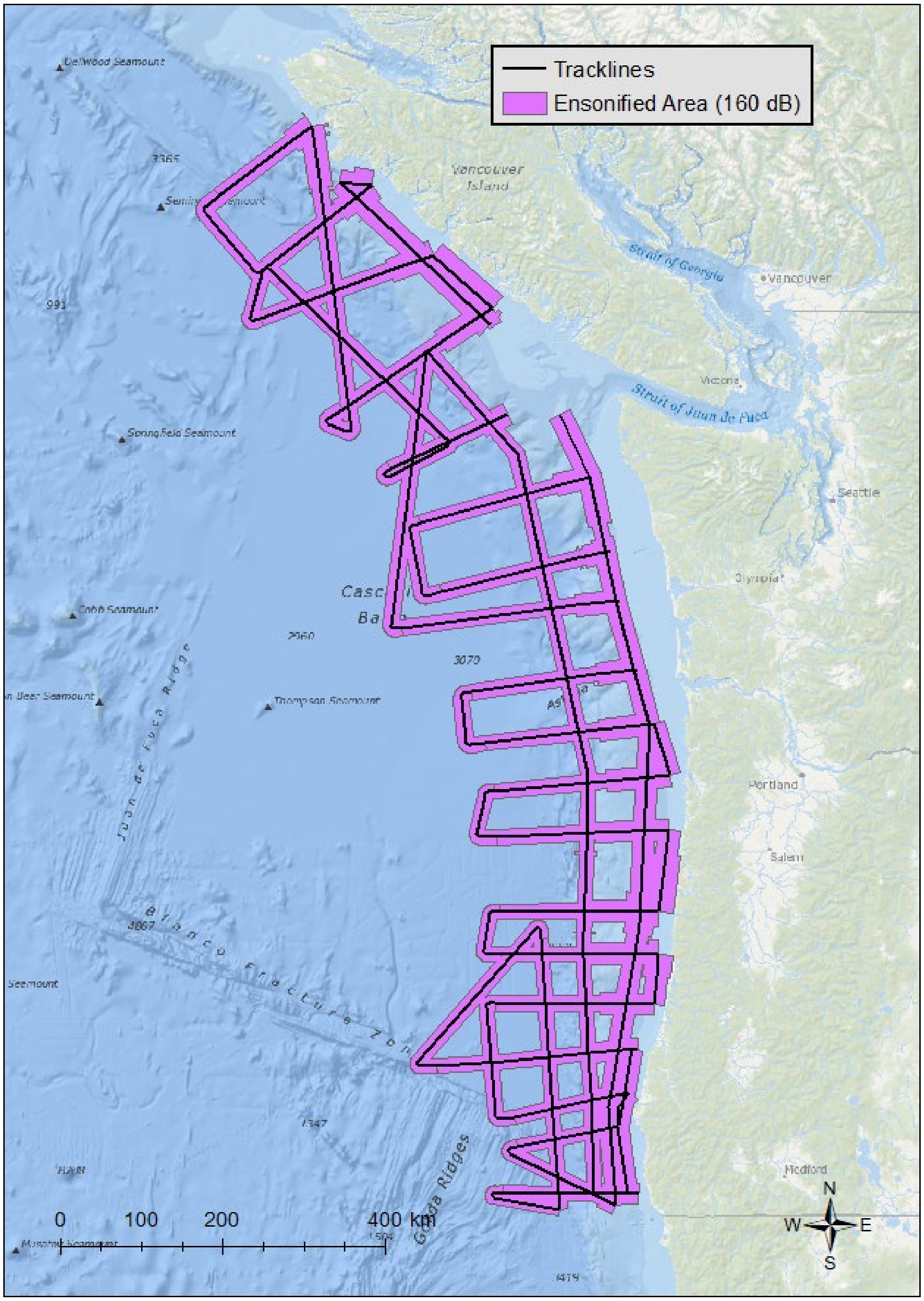

Figure 3. Map of the National Science Foundation and Lamont-Doherty Earth Observatory's high-energy marine seismic survey in the Northeast Pacific Ocean, Cascadia Subduction Zone.

4.1 Canadian Territorial Waters and the Action Area

Canada considers its territorial seas to extend out 12 nautical miles. A nation's territorial seas is the sovereign territory of that country. According to the draft Environmental Analysis that NSF prepared for this action, most of the survey lines will take place outside the 12 nautical mile line.

NMFS' jurisdiction under the ESA and MMPA only applies to the portions of the seismic survey that occur outside the 12 nautical mile boundary on the high seas.

The fact that portions of the proposed action fall both inside and outside of the 12 nautical mile boundary (the high seas under the ESA) presents us with a complexity. For ESA section 7 consultations, we are required to examine the effects of the action throughout the entire action area in making our jeopardy determination. However, we do not have authority under the ESA to authorize incidental take within the sovereign territory of Canada (i.e., within 12 nautical mile).

The ESA defines action area as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action." Although portions of the tracklines do not occur in the high seas (where the ESA has explicit jurisdiction), we are obligated to consider the effects of the action throughout the entire action area. Therefore, we must consider the 12 nautical mile boundary in relation to:

- The location of the tracklines, and
- The extent of the ensonified area.

By using GIS software, the L-DEO calculated the amount of survey tracklines and ensonified areas that were inside Canadian territorial waters. They then calculated MMPA take both inside Canadian territorial waters and for the entire action area (see Section 10.2).

This opinion considers two exposure scenarios to fulfill our requirements under the ESA:

1. Estimated exposure to determine the effects of the proposed action throughout the <u>entire action area</u> (inside and outside the 12 nautical mile boundary), including as part of our the jeopardy analysis, and
2. Estimated exposure in the portions of the action area where NMFS has jurisdiction under the ESA to exempt take from an otherwise lawful activity in an ITS.

5 Endangered Species Act-Listed Species and Proposed and Designated Critical Habitat Present in the Action Area

This section identifies the ESA-listed species and designated and proposed critical habitat that potentially occur within the action area (Table 5) that may be affected by the proposed action. Marine mammal species are expected to occur in the seismic survey area in both offshore and inshore waters. Migratory baleen whales, sperm whales, leatherback sea turtles, and Guadalupe fur seals are likely more common in the offshore region during the summer, but other animals like Southern Resident killer whales and feeding humpback whales are expected to occur closer to shore.

Table 5. Threatened and endangered species and designated and proposed critical habitat that may be affected by the proposed action.

Species	ESA Status	Critical Habitat	Recovery Plan
Marine Mammals – Cetaceans			
Blue Whale (*Balaenoptera musculus)*	E – 35 FR 18319	-- --	07/1998 10/2018 - Draft
Fin Whale (*Balaenoptera physalus)*	E – 35 FR 18319	-- --	75 FR 47538 07/2010
Gray Whale (*Eschrichtius robustus*) Western North Pacific Population	E – 35 FR 18319	-- --	-- --
Humpback Whale (*Megaptera novaeangliae*) – Central America DPS	E – 81 FR 62259	86 FR 21082	11/1991
Humpback Whale (*Megaptera novaeangliae*) – Mexico DPS	T – 81 FR 62259	86 FR 21082	11/1991
Killer Whale (*Orcinus orca*) – Southern Resident DPS	E – 70 FR 69903 Amendment 80 FR 7380	71 FR 69054 84 FR 99214 (Proposed Revision)	73 FR 4176 01/2008
North Pacific Right Whale (*Eubalaena japonica*)	E – 73 FR 12024	73 FR 19000	78 FR 34347 06/2013
Sei Whale (*Balaenoptera borealis*)	E – 35 FR 18319	-- --	12/2011
Sperm Whale (*Physeter macrocephalus*)	E – 35 FR 18319	-- --	75 FR 81584 12/2010
Marine Mammals—Pinnipeds			
Guadalupe Fur Seal (*Artocephalus townsendi*)	T – 50 FR 51252	-- --	-- --
Steller Sea Lion (*Eumetopias jubatus*) – Western DPS*	E – 55 FR 49204	58 FR 45269	73 FR 11872 2008
*The range of Western DPS of Steller sea lions is outside the action area; however, the critical habitat designated for the Western DPS in Oregon falls within the action area.			
Marine Reptiles			
Green Turtle (*Chelonia mydas*) – East Pacific DPS	T – 81 FR 20057	-- --	63 FR 28359 01/1998
Leatherback Turtle (*Dermochelys coriacea*)	E – 35 FR 8491	44 FR 17710 and 77 FR 4170	10/1991 – U.S. Caribbean, Atlantic, and Gulf of Mexico 63 FR 28359 05/1998 – U.S. Pacific

Species	ESA Status	Critical Habitat	Recovery Plan
Loggerhead Turtle (*Caretta caretta*) – North Pacific Ocean DPS	E – 76 FR 58868	-- --	63 FR 28359
Fishes			
Chinook Salmon (*Oncorhynchus tshawytscha)* – California Coastal ESU	T – 70 FR 37160	70 FR 52488	81 FR 70666
Chinook Salmon (*Oncorhynchus tshawytscha)* – Central Valley Spring-Run ESU	T – 70 FR 37160	70 FR 52488	79 FR 42504
Chinook Salmon (*Oncorhynchus tshawytscha)* – Lower Columbia River ESU	T – 70 FR 37160	70 FR 52629	78 FR 41911
Chinook Salmon (*Oncorhynchus tshawytscha)* – Puget Sound ESU	T – 70 FR 37160	70 FR 52629	72 FR 2493
Chinook Salmon (*Oncorhynchus tshawytscha)* – Sacramento River Winter-Run ESU	E – 70 FR 37160	58 FR 33212	79 FR 42504
Chinook Salmon (*Oncorhynchus tshawytscha)* – Snake River Fall-Run ESU	T – 70 FR 37160	58 FR 68543	80 FR 67386 (Draft)
Chinook Salmon (*Oncorhynchus tshawytscha)* – Snake River Spring/Summer Run ESU	T – 70 FR 37160	64 FR 57399	81 FR 74770 (Draft) 11-2017-Final
Chinook Salmon (*Oncorhynchus tshawytscha)* – Upper Columbia River Spring-Run ESU	E – 70 FR 37160	70 FR 52629	72 FR 57303
Chinook Salmon (*Oncorhynchus tshawytscha)* – Upper Willamette River ESU	T – 70 FR 37160	70 FR 52629	76 FR 52317
Chum Salmon (*Oncorhynchus keta*) – Columbia River ESU	T – 70 FR 37160	70 FR 52629	78 FR 41911
Chum Salmon (*Oncorhynchus keta*) – Hood Canal Summer-Run ESU	T – 70 FR 37160	70 FR 52629	72 FR 29121
Coho Salmon (*Oncorhynchus kisutch*) – Central California Coast ESU	E – 70 FR 37160	64 FR 24049	77 FR 54565
Coho Salmon (*Oncorhynchus kisutch*) – Lower Columbia River ESU	T – 70 FR 37160	81 FR 9251	78 FR 41911
Coho Salmon (*Oncorhynchus kisutch*) – Oregon Coast ESU	T – 73 FR 7816	73 FR 7816	81 FR 90780
Coho Salmon (*Oncorhynchus kisutch*) – Southern Oregon and Northern California Coasts ESU	T – 70 FR 37160	64 FR 24049	79 FR 58750
Eulachon (*Thaleichthys pacificus*) – Southern DPS	T – 75 FR 13012	76 FR 65323	9/2017

Species	ESA Status	Critical Habitat	Recovery Plan
Green Sturgeon (*Acipenser medirostris*) – Southern DPS	T – 71 FR 17757	74 FR 52300	2010 (Outline) 8/2018- Final
Sockeye Salmon (*Oncorhynchus nerka*) – Ozette Lake ESU	T – 70 FR 37160	70 FR 52630	74 FR 25706
Sockeye Salmon (*Oncorhynchus nerka*) – Snake River ESU	E – 70 FR 37160	58 FR 68543	80 FR 32365
Steelhead Trout (*Oncorhynchus mykiss*) – California Central Valley DPS	T – 71 FR 834	70 FR 52487	79 FR 42504
Steelhead Trout (*Oncorhynchus mykiss*) – Central California Coast DPS	T – 71 FR 834	70 FR 52487	81 FR 70666
Steelhead Trout (*Oncorhynchus mykiss*) – Lower Columbia River DPS	T – 71 FR 834	70 FR 52629	78 FR 41911
Steelhead Trout (*Oncorhynchus mykiss*) – Middle Columbia River DPS	T – 71 FR 834	70 FR 52629	74 FR 50165
Steelhead Trout (*Oncorhynchus mykiss*) – Northern California DPS	T – 71 FR 834	70 FR 52487	81 FR 70666
Steelhead Trout (*Oncorhynchus mykiss*) – Puget Sound DPS	T – 72 FR 26722	81 FR 9251	-- --
Steelhead Trout (*Oncorhynchus mykiss*) – Snake River Basin DPS	T – 71 FR 834	70 FR 52629	81 FR 74770 (Draft) 11-2017-Final
Steelhead Trout (*Oncorhynchus mykiss*) – South-Central California Coast DPS	T – 71 FR 834	70 FR 52487	78 FR 77430
Steelhead Trout (*Oncorhynchus mykiss*) – Southern California DPS	E – 71 FR 834	70 FR 52487	77 FR 1669
Steelhead Trout (*Oncorhynchus mykiss*) – Upper Columbia River DPS	T – 71 FR 834	70 FR 52629	72 FR 57303
Steelhead Trout (*Oncorhynchus mykiss*) – Upper Willamette River DPS	T – 71 FR 834	70 FR 52629	76 FR 52317
Boccaccio (*Sebastes paucispinis*) – Puget Sound/Georgia Basin DPS	E – 75 FR 22276 and 82 FR 7711	79 FR 68041	81 FR 54556 (Draft) 10/2017
Yelloweye Rockfish (*Sebastes rubberimus*) – Puget Sound/Georgia Basin DPS	T – 75 FR 22276 and 82 FR 7711	79 FR 68041	81 FR 54556 (Draft) 10/2017

6 Potential Stressors

The proposed action involves multiple activities, each of which can create stressors. Stressors are any physical, chemical, or biological entity that may directly or indirectly induce an adverse response either in an ESA-listed species or their designated critical habitat. During consultation, we deconstructed the proposed action to identify stressors that are reasonably certain to result from the proposed activities. These can be categorized as pollution (e.g., exhaust, fuel, oil, trash), vessel strikes, acoustic and visual disturbance (research vessel, multi-beam echosounder, sub-bottom profiler, acoustic Doppler current profiler, ocean bottom seismometers, ocean bottom nodes, and seismic airgun array), and entanglement in towed seismic equipment (hydrophone streamers). Below we provide information on these potential stressors. Furthermore, the proposed action includes several conservation measures described in Section 3.1.5. that are designed to minimize effects that may result from these potential stressors. While we consider all of these measures important and expect them to be effective in minimizing the effects of potential stressors, they do not completely eliminate the identified stressors. Nevertheless, we treat them as part of the proposed action and fully consider them when evaluating the effects of the proposed action (Section 3).

6.1 Pollution

The operation of the R/V *Marcus G. Langseth* and R/V *Oceanus* as a result of the proposed action may result in pollution from exhaust, fuel, oil, trash, and other debris. Air and water quality are the basis of a healthy environment for all species. Emissions pollute the air, which could be harmful to air-breathing organisms and lead to ocean pollution (Duce et al. 1991; Chance et al. 2015). The release of marine debris such as paper, plastic, wood, glass, and metal associated with vessel operations can also have adverse effects on marine species most commonly through entanglement or ingestion (Gall and Thompson 2015), while the discharge of gray water and wastewater (containing pollutants) from the vessels can degrade habitat for marine life. While lethal and non-lethal effects to air-breathing marine animals such sea turtles, birds, and marine mammals from marine debris are well documented, marine debris also adversely affects marine fish (Gall and Thompson 2015). In addition, the ocean bottom seismometers and nodes have anchors that will remain after the recording devices (nodes, seismometers) are retrieved, constituting marine debris.

6.2 Vessel Strikes

Seismic surveys necessarily involve vessel traffic within the marine environment, and the transit of any research vessel in waters inhabited by ESA-listed species carries the risk of a vessel strike. Vessel strikes are known to adversely affect ESA-listed marine mammals, sea turtles, and fishes (Laist et al. 2001; NMFS and USFWS 2008; Brown and Murphy 2010; Work et al. 2010b). The probability of a vessel collision depends on the number, size, and speed of vessels, as well as the distribution, abundance, and behavior of the species (Laist et al. 2001; Jensen and Silber 2004; Hazel et al. 2007; Vanderlaan and Taggart 2007; Conn and Silber 2013a). If an animal is struck by a research vessel, it may experience minor, non-lethal injuries, serious injuries, or death.

6.3 Operational Noise and Visual Disturbance from Vessels and Equipment

The proposed action will produce a variety of different sounds associated with the operation of the vessels and the equipment, including: multi-beam echosounders, sub-bottom profilers, acoustic Doppler current profilers, ROVs, ocean bottom seismometers, ocean bottom nodes, and airgun arrays that may produce an acoustic disturbance or otherwise affect ESA-listed species. Operational noise from vessels and equipment may also make the area in and around the sound source undesirable for marine life (prey species like fishes and invertebrates, as well as ESA-listed species), causing them to vacate a particular area. This stressor involves the presence of vessels (and associated equipment) that produce a visual disturbance that may affect ESA-listed marine mammals, sea turtles, and fishes.

6.4 Gear Interaction

The towed seismic equipment (e.g., airgun array and hydrophones) and the ROV's cables that will be used in the proposed seismic survey activities may pose a risk of entanglement to ESA-listed species. The gear used in the proposed action may also strike ESA-listed species while in use, or during deployment or retrieval, resulting in injury. This is a possibility for the oceans bottom seismometers in particular, as they will be lowered into the water from the vessel by a boom, and then, weighted down with an 80-kilogram steel anchor, would drop to the ocean floor. Entanglement can result in death or injury of marine mammals, sea turtles, and fishes (Moore et al. 2009a; Moore et al. 2009b; Deakos and H. 2011; Van Der Hoop et al. 2013a; Van der Hoop et al. 2013b; Duncan et al. 2017). Marine mammal, sea turtle, and fish entanglement, or bycatch, is a global problem that every year results in the death of hundreds of thousands of animals worldwide. Entangled marine mammals and sea turtles may drown or starve due to being restricted by gear, suffer physical trauma and systemic infections, and/or be hit by vessels due to an inability to avoid them. For smaller animals like sea turtles, death is usually quick, due to drowning. However, large whales can typically pull gear, or parts of it, off the ocean floor, and are generally not in immediate risk of drowning. Nonetheless, depending on the entanglement, towing gear for long periods may prevent a whale from being able to feed, migrate, or reproduce (Van der Hoop et al. 2017; Lysiak et al. 2018).

7 Species and Critical Habitat Not Likely to be Adversely Affected

NMFS uses two criteria to identify the ESA-listed species and critical habitats that are not likely to be adversely affected by the proposed action, as well as the effects of activities that are consequences of the Federal agency's proposed action. The first criterion is exposure, or some reasonable expectation of a co-occurrence, between one or more potential stressors associated with the proposed activities and ESA-listed species or designated critical habitat. If we conclude that an ESA-listed species or designated critical habitat is not likely to be exposed to the proposed activities, we must also conclude that the species or critical habitat is not likely to be adversely affected by those activities.

The second criterion is the probability of a response given exposure. ESA-listed species or designated critical habitat that co-occur with a stressor of the action but are not likely to respond to the stressor are also not likely to be adversely affected by the proposed action. We applied these criteria to the ESA-species and designated critical habitats in Table 5 and we summarize our results below.

The probability of an effect on a species or designated critical habitat is a function of exposure intensity and susceptibility of a species to a stressor's effects (i.e., probability of response). An action warrants a "may affect, not likely to be adversely affected" finding when its effects are wholly *beneficial, insignificant* or *discountable*. *Beneficial* effects have an immediate positive effect without any adverse effects to the species or habitat.

Insignificant effects relate to the size or severity of the impact and include those effects that are undetectable, not measurable, or so minor that they cannot be meaningfully evaluated. Insignificant is the appropriate effect conclusion when plausible effects are going to happen, but will not rise to the level of constituting an adverse effect.

Discountable effects are those that are extremely unlikely to occur. For an effect to be discountable, there must be a plausible adverse effect (i.e., a credible effect that could result from the action and that would be an adverse effect if it did impact a listed species), but it is very unlikely to occur.

In this section, we evaluate effects from the proposed action's stressors (Section 7.1) to numerous ESA-listed species and proposed or designated critical habitat that may be affected, but are not likely to be adversely affected by the proposed action. We also identify ESA-listed species and proposed or designated critical habitat that are not likely to be adversely affected by the proposed action (Section 7.2)

7.1 Stressors Not Likely to Adversely Affect Species

There are a number of stressors that could result from the proposed action as described in Section 6. We consider several of these stressors not likely to adversely affect species, and provide our rationale in the sections below. We also discuss the effects of these stressors on designated and proposed critical habitat in Section 7.2.5.

7.1.1 Pollution

Pollution in the form of vessel exhaust, fuel or oil spills or leaks, and trash or other debris resulting from the use of vessels as part of the proposed action could result in impacts to ESA-listed marine mammals, sea turtles, and fishes.

Vessel exhaust (i.e., air pollution) would occur during the entirety of the proposed action, during all vessel transit and operations, and could affect air-breathing ESA-listed species such as marine mammals and sea turtles. It is unlikely that vessel exhaust resulting from the operation of the R/V *Marcus G. Langseth* or R/V *Oceanus* would have a measurable impact on ESA-listed marine mammals or sea turtles given the relatively short duration of the proposed action (~37 days), the brief amount of time that whales and sea turtles spend at the surface, and the various regulations to minimize air pollution from vessel exhaust, such as NSF's compliance with the

Act to Prevent Pollution from Ships. For these reasons, the effects that may result from vessel exhaust on ESA-listed marine mammals and sea turtles are considered insignificant.

Discharges into the water from research vessels (the R/V *Marcus G. Langseth* and the R/V *Oceanus*, and the support vessel) in the form of wastewater or leakages of fuel or oil are possible, though effects of any spills to ESA-listed marine mammals, sea turtles, and fishes considered in this opinion will be minimal, if they occur at all. Wastewater from the vessels would be treated in accordance with U.S. Coast Guard standards. The potential for fuel or oil leakages is extremely unlikely. An oil or fuel leak could pose a significant risk to the vessel and its crew and actions to correct a leak should occur immediately to the extent possible. The research vessels used during the National Science Foundation-funded seismic survey have spill-prevention plans, which allow a rapid response to a spill in the event one occurs. In the event that a leak should occur, the response would prevent a widespread, high dose contamination (excluding the remote possibility of severe damage to the vessels) that will impact ESA-listed species directly or pose hazards to their food sources that may be part of proposed or designated critical habitat in the action area. Because the potential for oil or fuel leakage is extremely unlikely to occur, we find that the risk from this potential stressor on ESA-listed marine mammals, sea turtles, and fishes is discountable.

Trash or other debris resulting from the proposed action may affect ESA-listed marine mammals, sea turtles, and fishes. Any marine debris (e.g., plastic, paper, wood, metal, glass) that might be released would be accidental. The National Science Foundation follows standard, established guidance on the handling and disposal of marine trash and debris during the seismic survey. The gear used in the proposed action may also result in marine debris. The ocean bottom nodes would be deployed and retrieved by the ROV, so there would be no components of those devices left behind. However, the ocean bottom seismometers would be released from the attached anchor and float to the surface for retrieval, leaving the anchor behind as debris on the ocean floor. There would be a total of 115 ocean bottom seismometer anchors left behind. Anchors that are placed within the boundaries of the Olympic Coast National Marine Sanctuary would be made of cement. Other ocean bottom seismometers would be made of steel. Although these anchors can be considered debris, we do not believe them to pose an entanglement risk or other hazards for ESA-listed marine mammals, sea turtles, or fishes. The small amount of debris created by the anchors as a result of the proposed action compared to the relative size of the available habitat used by ESA-listed species is insignificant. Because the potential for accidental release of trash is extremely unlikely to occur, we find that the effects from this potential stressor on ESA-listed marine mammals, sea turtles, and fishes are discountable. The marine debris created by the ocean bottom seismometers is minor, thus we find that the effects from this potential stressor on ESA-listed marine mammals, sea turtles, and fishes are insignificant.

Therefore, we conclude that pollution by vessel exhaust, wastewater, fuel or oil spills or leaks, and trash or other debris may affect, but is not likely to adversely affect ESA-listed species, and will not be analyzed further in this opinion.

7.1.2 Vessel Strikes

Vessel traffic associated with the proposed action carries the risk of vessel strikes of ESA-listed marine mammals, sea turtles, and fishes. In general, the probability of a vessel collision and the associated response depends, in part, on size and speed of the vessel. The R/V *Marcus G. Langseth* has a length of 235 feet (72 meters) and the operating speed during seismic data acquisition is typically approximately 9.3 kilometers per hour (5 knots). When not towing seismic survey gear, the R/V *Marcus G. Langseth* typically transits at 18.5 kilometers per hour (10 knots). The R/V *Oceanus* is 177 feet (54 meters) in length, and cruises up to 20.3 kilometers per hour (11 knots). During the deployment and retrieval of ocean bottom seismometers and ocean bottom nodes, the R/V *Oceanus* will be traveling at a much slower speed. The majority of vessel strikes of large whales occur when vessels are traveling at speeds greater than approximately 18.5 kilometers per hour (10 knots), with faster travel, especially of large vessels (80 meters [262.5 feet] or greater), being more likely to cause serious injury or death (Laist et al. 2001; Jensen and Silber 2004; Vanderlaan and Taggart 2007; Conn and Silber 2013a).

Much less is known about vessel strike risk for sea turtles, but it is considered an important injury and mortality risk within the action area (Lutcavage et al. 1997). Based on behavioral observations of sea turtle avoidance of small vessels, green turtles may be susceptible to vessel strikes at speeds as low as 3.7 kilometers per hour (2 knots;(Hazel et al. 2007). If an animal is struck by a vessel, responses can include death, serious injury, and/or minor, non-lethal injuries, with the associated response depending on the size and speed of the vessel, among other factors (Laist et al. 2001; Jensen and Silber 2004; Vanderlaan and Taggart 2007; Conn and Silber 2013b).

Each of the ESA-listed fish species considered in this opinion are thought to spend at least some time in the upper portions of the water column where they may be susceptible to vessel strike. Despite these species' use of the upper portion of the water column for at least some of their life history, in most cases, we would anticipate the ESA-listed fishes considered in this opinion would be able to detect vessels or other in-water devices and avoid them. Fish are able to use a combination of sensory cues to detect approaching vessels, such as sight, hearing, and their lateral line (for nearby changes in water motion). A study on fish behavioral responses to vessels showed that most adults exhibit avoidance responses to engine noise, sonar, depth finders, and fish finders (Jørgensen et al. 2004), reducing the potential for vessel strikes. Misund (1997) found that fish ahead of a ship showed avoidance reactions at ranges of 50 to 350 meters (160 to 490 feet). When the vessel passed over them, some fish responded with sudden escape responses that included movement away from the vessel laterally or through downward compression of the school. In an early study conducted by Chapman and Hawkins (1973), the authors observed avoidance responses of herring from the low-frequency sounds of large vessels or accelerating small vessels. Avoidance responses quickly ended within ten seconds after the vessel departed. Conversely, Rostad (2006) observed that some fish (likely schools of herring) are attracted to different types of drifting and stationary vessels (e.g., research vessels) of varying sizes, noise levels, and habitat locations, as well as moving commercial vessels. While we are not aware of studies specifically focusing on ESA-listed fishes' reactions to vessels, we cannot rule out either occurrence during the proposed action.

Several conservation measures proposed by the NMFS Permits and Conservation Division and/or National Science Foundation and L-DEO will minimize the risk of vessel strike to marine mammals and sea turtles, such as the use of PSOs, and ship crew keeping watch while in transit. In addition, the overall level of vessel activity associated with the proposed action is low relative to the large size of the action area, further reducing the likelihood of a vessel strike of an ESA-listed species.

While vessel strikes of marine mammals, sea turtles, and fishes during seismic survey activities are possible, we are not aware of any definitive case of a marine mammal, sea turtle, or fish being struck by a vessel associated with NSF seismic surveys. The R/V *Marcus G. Langseth* will be traveling at generally low speeds, reducing the probability of a vessel strike for marine mammals (Kite-Powell et al. 2007; Vanderlaan and Taggart 2007). The R/V *Oceanus*, while capable of traveling faster while in transit (11 knots to the R/V *Marcus G. Langseth*'s 10 knots), is smaller than the R/V *Marcus G. Langseth*, making it more maneuverable and less likely to strike an ESA-listed species. Both vessels will maintain watches while in transit. Our expectation of vessel strike being extremely unlikely to occur is due to the hundreds of thousands of kilometers the R/V *Marcus G. Langseth* has traveled without a reported vessel strike, general expected movement of marine mammals and sea turtles away from or parallel to the R/V *Marcus G. Langseth*, as well as the generally slow movement of the R/V *Marcus G. Langseth* during most of its travels (Holst and Smultea 2008b; Hauser and Holst 2009; Holst 2010). In addition, adherence to observation and avoidance procedures is also expected to avoid vessel strikes of marine mammals and sea turtles. All factors considered, we have concluded vessel strike of ESA-listed species by the research vessels is extremely unlikely to occur. Therefore, we conclude that vessel strike may affect, but is not likely to adversely affect ESA-listed species and will not be analyzed further in this opinion.

7.1.3 Operational Noise and Visual Disturbance of Vessels and Equipment

The research vessels associated with the proposed action may cause visual or auditory disturbances to ESA-listed species that spend time near the surface or in the upper parts of the water column, such as marine mammals, sea turtles, and fishes, which may generally disrupt their behavior. Assessing whether these sounds may adversely affect ESA-listed species involves understanding the characteristics of the acoustic sources, the species that may be present in the vicinity of the sound, and the effects that sound may have on the physiology and behavior of those species. Although it is known that sound is important for marine mammal communication, navigation, and foraging (NRC 2003b; NRC 2005a), there are many unknowns in assessing impacts of sound, such as the potential interaction of different effects and the significance of responses by marine mammals to sound exposures (Nowacek et al. 2007; Southall et al. 2007b). Other ESA-listed species such as sea turtles and fishes are often considered less sensitive to anthropogenic sound, but given that much less is known about how they use sound, the impacts of anthropogenic sound are difficult to assess (Popper et al. 2014b; Nelms et al. 2016). Nonetheless, depending on the circumstances, exposure to anthropogenic sounds may result in auditory injury, changes in hearing ability, masking of important sounds, behavioral responses, as well as other physical and physiological responses (see Section 10.2.2).

Studies have shown that vessel operations can result in changes in the behavior of marine mammals, sea turtles, and fishes (Patenaude et al. 2002; Richter et al. 2003; Hazel et al. 2007; Smultea et al. 2008a; Holt et al. 2009; Luksenburg and Parsons 2009; Noren et al. 2009b). In many cases, particularly when responses are observed at great distances, it is thought that animals are likely responding to sound more than the visual presence of vessels (Evans et al. 1992; Blane and Jaakson 1994; Evans et al. 1994). At close distances animals may not even differentiate between visual and acoustic disturbances created by vessels and simply respond to the combined disturbance. Nonetheless, it is generally not possible to distinguish responses to the visual presences of vessels from those to the sounds associated with those vessels. We consider the effects to marine mammals, sea turtles, and fishes from the visual presence of vessels associated with the proposed action to be insignificant.

Sounds emitted by large vessels can be characterized as low-frequency, continuous, or tonal, and sound pressure levels at a source will vary according to speed, burden, capacity, and length (Richardson et al. 1995b; Kipple and Gabriele 2007; McKenna et al. 2012). Source levels for 593 container ships transits were estimated from long-term acoustic recording received levels in the Santa Barbara shipping channel, and a simple transmission loss model using Automatic Identification System data for source-receiver range (McKenna et al. 2013a). Vessel noise levels could vary 5 to 10 dB depending on transit conditions. Given the sound propagation of low frequency sounds, a large vessel in this sound range can be heard 139 to 463 kilometers (75.1 to 250 nautical miles) away (Polefka 2004). Hatch et al. (2008) measured commercial ship underwater noise levels and reported average source level estimates (71 to 141 hertz, re: 1 μPa [rms] ± standard error) for individual vessels ranged from 158 ± 2 dB (research vessel) to 186 ± 2 dB (oil tanker). McKenna et al (2012), in a study off Southern California, documented different acoustic levels and spectral shapes observed from different modern vessel-types, illustrating the variety of possible noise levels created by the diversity of vessels that may be present.

Very little research exists on sea turtle responses to vessel noise disturbance. Currently, there is nothing in the available literature specifically aimed at studying and quantifying sea turtle response to vessel noise. However, a study examining vessel strike risk to green sea turtles suggests that sea turtles may habituate to vessel sound and may be more likely to respond to the sight of a vessel rather than the sound of a vessel, although both may play a role in prompting reactions (Hazel et al. 2007). Regardless of the specific stressor associated with vessels to which turtles are responding, they only appear to show responses (i.e., avoidance behavior) at approximately 10 meters (32.8 feet) or closer (Hazel et al. 2007). Therefore, the noise from vessels is not likely to affect sea turtles from further distances, and disturbance may only occur if a sea turtle hears a vessel nearby or sees it as it approaches.

All fish species can detect vessel noise due to its low-frequency content and their hearing capabilities. Therefore, ESA-listed fishes could be exposed to a range of vessel noises, depending on the source and context of the exposure. In the near field, fish are able to detect water motion as well as visually locate an oncoming vessel. In these cases, most fishes located in close proximity that detect the vessel either visually, via sound and motion in the water would be capable of avoiding the vessel or move away from the area affected by vessel sound. Thus, fish are more likely to react to vessel noise at close range than to vessel noise emanating from a greater distance away.

The contribution of vessel noise by the R/V *Marcus G. Langseth* and the R/V *Oceanus* is likely small in the overall regional sound field. Brief interruptions in communication via masking are possible, but unlikely given the habits of marine mammals and fish to move away from vessels, either as a result of engine noise, the physical presence of the vessel, or both (Mitson and Knudsen 2003; Lusseau 2006). Also, as stated, sea turtles are most likely to habituate and are shown to be less effected by vessel noise at distances greater than 10 meters (32.8 feet) (Hazel et al. 2007). In addition, during research operations, the R/V *Marcus G. Langseth* and R/V *Oceanus* will be traveling at slow speeds, reducing the amount of noise produced by the propulsions system (Kite-Powell et al. 2007; Vanderlaan and Taggart 2007). The distance between the research vessel and observed marine mammals and sea turtles, per avoidance protocols, will also minimize the potential for acoustic disturbance from engine noise. Because the potential acoustic interference from engine noise will be undetectable or so minor that it cannot be meaningfully evaluated, we find that the risk from this potential stressor is insignificant. Therefore, we conclude that acoustic interference from engine noise may affect, but is not likely to adversely affect ESA-listed marine mammals, sea turtles, or fishes, and will not be analyzed further.

Unlike vessels, which produce sound as a byproduct of their operations, multi-beam echosounders, sub-bottom profilers, acoustic Doppler current profilers, acoustic release transponders, ocean bottom seismometers, ocean bottom nodes, ROVs, and airgun arrays are designed to actively produce sound, and as such, the characteristics of these sound sources are deliberate and under control. The ocean bottom seismometers have an acoustic release transponder that transmits a signal to the instrument at a frequency of 8 to 11 kilohertz and a response is received at a frequency of 11.5 to 13 kilohertz (operator selectable), to activate and release the instrument. The transmitting beam pattern is 55 degrees. The sound source level is approximately 93 dB. Other components of the ROV (e.g., side-looking sonars) have operating frequencies that are high frequencies.

The functional hearing ranges of ESA-listed sea turtles are not well understood and vary by species. In general, the available information on sea turtle hearing indicates that their hearing thresholds are less than 1 kilohertz (Moein et al. 1994). Loggerhead sea turtles are thought to have a functional hearing range of 250 to 750 hertz (Bartol et al. 1999), Kemp's ridley sea turtles a range of 100 to 500 hertz, and green sea turtles 100 to 800 hertz (Ketten and Bartol 2005),

The multibeam echosounder and the sub-bottom profiler will not be operated while the vessel is in transit. These devices will be used during the seismic survey, and we expect that, because the sound from the airguns is greater than that produced by the multibeam echosounder or the sub-bottom profiler, ESA-listed marine mammals, sea turtles, and fish will be affected by the airgun array to an extent that does not allow us to distinguish the effects from the operation of these devices. However, the sounds from operation of this equipment is discussed further in this opinion.

7.1.4 Gear Interaction

There is a variety of gear proposed for use during the proposed action that might entangle, strike, or otherwise interact with ESA-listed species in the action area.

Towed gear from the seismic survey activities pose a risk of entanglement to ESA-listed marine mammals and sea turtles. The towed hydrophone streamer could come in direct contact with ESA-listed species and sea turtle entanglements have occurred in towed gear from seismic survey vessels. We are not aware of any cases of leatherback sea turtles entanglement. However, a National Science Foundation-funded seismic survey off the coast of Costa Rica during 2011 recovered a dead olive ridley turtle (*Lepidochelys olivacea*) in the foil of towed seismic equipment; it is unclear whether the sea turtle became lodged in the foil pre- or post mortem (Spring 2011). However, entanglement is highly unlikely due to the towed hydrophone streamer design, as well as observations of sea turtles investigating the towed hydrophone streamer and not becoming entangled or operating in regions of high sea turtle density and entanglements not occurring (Holst et al. 2005b; Holst et al. 2005a; Hauser 2008; Holst and Smultea 2008a). The towed hydrophone streamer is rigid and as such will not encircle, wrap around, or in any other way entangle any of the marine mammals considered during this consultation. We expect the taut cables will prevent entanglement. Furthermore, marine mammals are expected to avoid areas where the airgun array is actively being used, meaning they will also avoid towed gear. We are not aware of any entanglement events with ESA-listed marine mammals or sea turtles with the towed gear proposed for use in this action.

The ocean bottom nodes will be placed on the seafloor by the ROV operated from the R/V *Oceanus*, and the ocean bottom seismometers will be dropped from the sea surface by the R/V *Oceanus*. We do not expect ESA-listed marine mammals or sea turtles to be at the ocean bottom, so the concerns about equipment strike would primarily be while the ROV is moving up and down the water column, deploying the ocean bottom nodes. Similarly, the ocean bottom seismometers pose a risk to ESA-listed marine mammals and sea turtles as they are being deployed, and dropping to the ocean floor. The ROV camera would allow the operator to avoid any sea turtles or marine mammals that may be present in the water column as the equipment for the ocean bottom nodes travels up and down the water column. We expect an ESA-listed marine mammal or sea turtles to perceive the disturbance and be able to detect the ROV or ocean bottom seismometers, exhibit avoidance behavior, and move out of the way.

ESA-listed fish species in the action area (e.g., green sturgeon, salmon, steelhead, and eulachon) could be entangled or struck by equipment used during the seismic survey. ESA-listed salmon, steelhead, and eulachon are distributed throughout the water column, while green sturgeon occur at the ocean bottom (typically in depths less than 110 meters). The ocean bottom seismometers, ocean bottom nodes, and the ROV will operate at or near the ocean floor. The towed hydrophone array, the PAM hydrophone (both towed near the surface), and the towed airgun array (towed at 12 meters below the surface) pose similar risks to ESA-listed fishes species. However, we consider the possibility of equipment entanglement or strike to be remote because of fishes' ability to detect the equipment moving through the water and move out of the way. In addition, the personnel operating the ROV will be able to use its camera to avoid ESA-listed fishes.

Although the towed hydrophone streamer or passive acoustic monitoring array could come in direct contact with an ESA-listed species, entanglements are highly unlikely and considered discountable. Based upon extensive deployment of this type of equipment with no reported entanglement and the nature of the gear that is likely to prevent it from occurring, we find the probability of adverse impacts to ESA-listed species to be discountable; therefore, gear interactions may affect, but are not likely to adversely affect any ESA-listed species, and will not be analyzed further in this opinion.

7.1.5 Stressors Considered Further

The only potential stressor that is likely to adversely affect some ESA-listed species within the action area is sound fields produced by the seismic airgun array, multi-beam echosounder, sub-bottom profiler, acoustic Doppler current profiler, acoustic release transponder, ROV, ocean bottom seismometers, and ocean bottom nodes. This stressor and these sound sources associated with seismic survey activities may adversely affect the ESA-listed marine mammals, sea turtles, and fishes and are further analyzed and evaluated in detail in Section 10.

7.2 Species Not Likely to be Adversely Affected

There are a number of ESA-listed species, as well as designated and proposed critical habitat, that could potentially be in the action area and possibly be exposed to the stressors associated with the proposed action. As discussed previously, most of the stressors associated with the proposed action are not likely to adversely affect any of the listed species in the action area but acoustic sources (i.e., sound fields by the seismic airguns and the other equipment used in the survey) may result in adverse effects for some ESA-listed species. However, for the reasons discussed below, we consider green and loggerhead sea turtles, North Pacific right whale, Western North Pacific gray whale, Southern California DPS steelhead, and Puget Sound/Georgia Basin DPS boccaccio and yelloweye rockfish may be affected, but are not likely to be adversely affected by noise from these sound sources.

7.2.1 Green and Loggerhead Sea Turtles

Endangered Species Act-listed sea turtles may be present in the action area. Green turtle (*Chelonia mydas*) East Pacific distinct population segment (DPS) and loggerhead sea turtle (*Caretta caretta*) North Pacific DPS range along the West Coast of the United States. However, green and loggerhead turtles are only rarely found in Washington or Oregon waters (WDFW 2012). Because of their scarcity in the waters in and around the action area, we believe it is extremely unlikely that green or loggerhead sea turtles will be exposed to any of the stressors associated with the proposed action, and the effects are discountable. Therefore, we conclude that the proposed action may affect, but is not likely to adversely affect these species.

7.2.2 North Pacific Right Whale

North Pacific right whales occur in subpolar to temperate waters. They are generally migratory, with at least a portion of the population moving between summer feeding grounds in temperate or high latitudes and winter calving areas in warmer waters (Kraus et al. 1986; Clapham et al. 2004a). Historical whaling records provide virtually the only information on North Pacific right whale distribution (Gregr 2011). This species historically occurred across the Pacific Ocean north of 35 degrees North, with concentrations in the Gulf of Alaska, eastern Aleutian Islands, south-central Bering Sea, Okhotsk Sea, and the Sea of Japan (Omura et al. 1969; Scarff 1986a; Clapham et al. 2004a; Shelden et al. 2005; Gregr 2011; Ivashchenko et al. 2013). North Pacific right whales were probably never common along the west coast of North America (Scarff 1986a; Brownell Jr. et al. 2001), although historically, the North Pacific right whale was sighted in waters off the coast of British Columbia and Washington, Oregon, and California (Scarff 1986b; Clapham et al. 2004b). The rarity of reports for North Pacific right whales in more southern coastal areas in winter in either historical or recent times suggests that their breeding grounds may have been offshore (Clapham et al. 2004a). Presently, sightings are extremely rare, occurring primarily in the Okhotsk Sea and the eastern Bering Sea (Brownell Jr. et al. 2001; Shelden et al. 2005; Wade et al. 2006; Zerbini et al. 2010).

In October 2013, a North Pacific right whale sighting was made off the Strait of Juan de Fuca with a group of humpback whales moving south into the offshore area of the U.S. Navy's Northwest Training and Testing action area (Navy 2015). There have also been four sightings, each of a single North Pacific right whale, in California waters within approximately the last 30 years (in 1988, 1990, 1992, and 2017;(Carretta et al. 1994; Brownell et al. 2001; Price 2017). Various sightings of North Pacific right whales in the general vicinity of the action area have occurred on an irregular basis. Two North Pacific right whales were sighted in 1983 on Swiftsure Bank at the entrance to the Strait of Juan de Fuca (Osborne et al. 1988). There were no sightings of North Pacific right whales during six NMFS vessel surveys conducted in summer and fall off California, Oregon, and Washington from 1991 through 2008 (Barlow 2010).

In addition to the low population numbers (likely less than 1,000) in the North Pacific Ocean, because only a few individuals have been observed (Brownell Jr. et al. 2001; Wade et al. 2006), even given more recent sightings and detections, this species is considered extremely rare in the action area. The seismic activities of the proposed action will take place in June and July when we expect that North Pacific right whales to be on their summer feeding grounds outside of the action area in the Bering Sea, Gulf of Alaska, Okhotsk Sea, and the Northwestern Pacific Ocean (Muto et al. 2019). Based on this information, there is a very low probability of encountering this species anywhere in the coastal and offshore waters in the action area during the proposed seismic surveys. As a result, potential acoustic noise from the airgun array, multi-beam echosounder, sub-bottom profiler, acoustic Doppler current profiler, and acoustic release transponder on North Pacific right whales is discountable. Therefore, we conclude that the National Science Foundation and L-DEO's seismic survey activities may affect, but are not likely to adversely affect ESA-listed North Pacific right whales.

7.2.3 Gray Whale Western North Pacific Population

The Western North Pacific population of gray whales exhibits extensive plasticity in the occurrence of animals, shifting use of areas within and between years, as well as over longer time frames, such as in response to oceanic climate cycles (e.g., El Niño-Southern Oscillation, Pacific Decadal Oscillation, and Arctic Oscillation; (Weller et al. 2012) (Gardner and Chávez-Rosales 2000). The population's typical distribution extends south along Japan, the Koreas, and China from the Kamchatka Peninsula (Omura 1988; Kato and Kasuya. 2002; IWC 2003; Weller et al. 2003; Reeves et al. 2008). Other possible range areas include Vietnam, the Philippines, and Taiwan, although only historical whaling records support occurrence in these areas (Henderson 1990; Ilyashenko 2009). The range has likely contracted from the Koreas and other southern portions of the range versus pre-whaling periods. Prey availability and, to a lesser extent, sea ice extent, are probably strong influences on the habitats used by the Western North Pacific population of gray whales (Moore 2000; Clarke and Moore 2002).

The Eastern and Western North Pacific populations of gray whales were once considered geographically separated along either side of the ocean basin, but recent photo-identification, genetic, and satellite tracking data refute this. Two individuals from the Western North Pacific population of gray whales have been satellite tracked from Russian foraging areas east along the Aleutian Islands, through the Gulf of Alaska, and south to the Washington and Oregon coasts in one case (Mate et al. 2011), and to the southern tips of Baja California and back to Sakhalin Island in another (IWC 2012). Comparisons of catalogues of Eastern and Western North Pacific populations of gray whales have thus far identified 24 individuals from the Western North Pacific population of gray whales occurring on the eastern side of the basin during winter and spring (Burdin et al. 2011; Weller et al. 2013); for reference, there are about 26,960 individuals in the Eastern North Pacific population (NMFS 2019a). During one field season off Vancouver Island, individuals from the Western North Pacific population of gray whales were found to constitute six of 74 (8.1 percent) of photo-identifications (Weller et al. 2012). In addition, two genetic matches with the Western North Pacific population of gray whales off Santa Barbara, California have been made (Lang et al. 2011). Individuals have also been observed migrating as far as Central Baja Mexico (Weller et al. 2012).

From this overview, it is apparent that individuals from the Western North Pacific population of gray whales could be found within the action area. It is possible that an individual or individuals from the Western North Pacific population of gray whale could be unintentionally impacted by the proposed seismic survey activities. However, given their low occurrence in the action area we find it highly unlikely that any individuals from the Western North Pacific population of gray whales will be affected by the proposed seismic survey activities. The few photo-identification matches from collaborating researchers have occurred primarily in the spring during the migration (Weller et al. 2012), which is not when the field work will occur (the seismic survey activities are planned for June and July 2021). Due to this, Western North Pacific population of gray whales will have a very low likelihood of being exposed to acoustic stressors produced by the seismic airgun array, multi-beam echosounder, sub-bottom profiler, acoustic Doppler current profiler, and acoustic release transponder used during the seismic survey activities. Therefore, we believe the potential impacts to the Western North Pacific population of gray whale as a result of the proposed seismic survey activities will be discountable. We conclude that the proposed seismic survey activities may affect, but are not likely to adversely affect ESA-listed Western North Pacific population of gray whales.

7.2.4 Steelhead Trout—Southern California DPS

As with other salmonids, Southern California DPS steelhead spend a portion of their life cycle in the marine environment, including the action area, and could potentially be exposed to the proposed action (e.g., sound fields created by the seismic airguns and other equipment used in the survey).

Limited information exists on Southern California steelhead runs. Based on combined estimates for the Santa Ynez, Ventura, and Santa Clara rivers, and Malibu Creek, an estimated 32,000 to 46,000 adult steelhead occupied this DPS historically. In contrast, less than 500 adults are estimated to occupy the same four waterways presently. The last estimated run size for steelhead in the Ventura River, which has its headwaters in Los Padres National Forest, is 200 adults (Busby et al. 1996a).

Given the extremely low abundance of ESA-listed Southern California steelhead in general and within the action area and the limited likelihood of co-occurrence with the proposed action's stressors, the likelihood of the proposed action adversely affecting Southern California steelhead is so low as to be discountable.

7.2.5 Puget Sound/Georgia Basin DPS Boccaccio and Yelloweye Rockfish

Puget Sound/Georgia Basin DPS boccaccio and yelloweye rockfish are those that reside in Puget Sound/Georgia Basin. They could be exposed to stressors associated with the proposed action while the research vessels are transiting back to port in Seattle, Washington.

ESA-listed rockfishes are largely benthic, with juveniles occupying shallow, nearshore environments, favoring rocky substrate and kelp habitats. Sub-adult and adult rockfishes occupy deeper waters, 30 to 425 meters.

The vessels associated with the proposed action will operate in the upper levels of the water column, where Puget Sound/Georgia Basin DPS boccaccio and yelloweye rockfish are not likely to be. The stressors that accompany vessel transit—pollution, noise, visual disturbance—were analyzed in Section 7.1 and found to be insignificant or discountable, respectively, to ESA-listed fishes. We concluded that the proposed action may affect, but is not likely to adversely affect Puget Sound/Georgie Basin DPS boccaccio or yelloweye rockfish, and will not be analyzed further in this opinion.

7.2.6 Critical Habitat Not Likely to be Adversely Affected

The action area includes the waters off Oregon, Washington, and Vancouver Island, where the seismic survey will occur, as well as the locations where the research vessels will transit to and from the survey area. The vessels will be departing the Port of Newport, Oregon, and returning to the Port of Seattle, Washington at the conclusion of the action. There are a number of critical habitat areas that overlap with the action area that are not likely to be adversely affected by the proposed action, and we present our rationale for this effects conclusion below.

7.2.6.1 Southern Resident Killer Whale Critical Habitat

There are two portions of critical habitat – one designated and one proposed – for Southern Resident killer whales in the action area (Figure 4). Different parts of the proposed action will occur in each portion of critical habitat (proposed and designated), and the effects are discussed below.

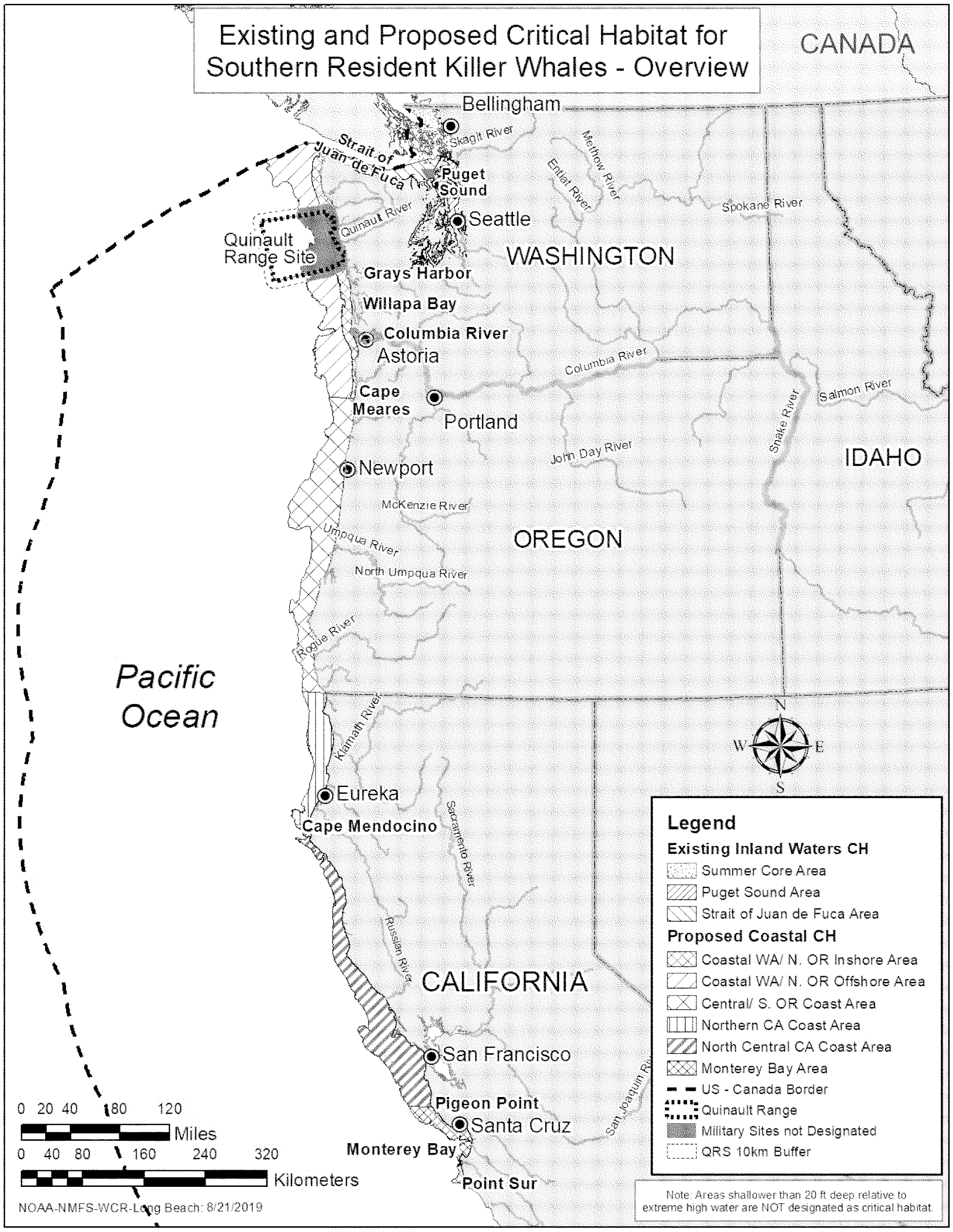

Figure 4. Southern Resident killer whale proposed and designated critical habitat.

Designated Critical Habitat

In 2006, NMFS designated critical habitat for the Southern Resident DPS of killer whale (71 FR 69054). The designated critical habitat, located in three specific areas in Washington: (1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; (2) Puget Sound; and (3) the Strait of Juan de Fuca, overlaps with the action area because the R/V *Langseth* will transit back to port in Seattle. No other parts of the proposed action (e.g., seismic activities, placement of equipment) will occur in this portion of designated critical habitat.

The physical and biological features essential to the conservation of Southern Resident DPS of killer whales include: (1) water quality to support growth and development; (2) prey species of sufficient quantity, quality, and availability to support individual growth, reproduction and development, as well as overall population growth; and (3) inter-area passage conditions to allow for migration, resting, and foraging.

The only stressors associated with the proposed action that would occur in the designated critical habitat would be those associated with vessel traffic while the research vessels transit back to port. These stressors would include noise associated with vessel operation, pollution from the vessel, and the visual disturbance created by the vessel.

The PBFs for the designated critical habitat are the same as for the proposed critical habitat; see the section below for our analysis of the effects of the proposed action on these PBFs.

Proposed Critical Habitat

On September 19, 2019, NMFS proposed to revise the critical habitat designation for Southern Resident killer whales by expanding it to include six new areas along the U.S. West Coast, while keeping the current designated critical habitat area in Washington. The proposed new areas along the U.S. West Coast include roughly 15,626 square miles of marine waters between the 6.1-meter depth contour and the 200-meter depth contour from the U.S. international border with Canada south to Point Sur, California.

The proposed critical habitat overlaps with the action area. Specifically, the planned seismic survey lines off the coasts of Oregon and Washington are within the proposed critical habitat and ocean bottom seismometers and nodes will be placed within the proposed critical habitat. The research vessels (the R/V *Langseth*, the R/V *Oceanus*, and the support vessel) will transit through the proposed critical habitat.

The identified PBFs that are essential to the conservation of the Southern Resident killer whale DPS proposed critical habitat are: (1) water quality to support growth and development; (2) prey species of sufficient quantity, quality, and availability to support individual growth, reproduction and development, as well as overall population growth; and (3) inter-area passage conditions to allow for migration, resting, and foraging.

NMFS previously considered identifying "sound levels that do not exceed thresholds that inhibit communication or foraging activities or result in temporary or permanent hearing loss" as a potential essential feature of the whales' inland critical habitat (69 FR 76673; December 22, 2004), but ultimately concluded that sufficient information was not available to do so (NMFS 2019a). An acoustic environment, or soundscape, in which Southern Resident killer whales can detect and interpret sounds is critical for carrying out basic life functions including communication, navigation, and foraging. We assess adverse habitat-related effects of anthropogenic sound by evaluating impacts to the prey and passage PBFs of critical habitat for Southern Resident killer whales. That is, we evaluate whether acoustic stressors resulting from the proposed action might alter the conservation value of habitat by reducing the quantity, quality, or availability of the whales' prey in a particular foraging area, by reducing the effective echolocation space for the whales to forage, or by creating a barrier that restricts movements through or within an area necessary for migration, resting, or foraging.

We do not expect there to be substantial effects to water quality as a result of the proposed action (see Section 7.1.1), and therefore do not expect the first PBF of the proposed critical habitat to be affected. The second PBF concerns the availability of sufficient prey species in the proposed critical habitat, to support Southern Resident killer whales. As described in Section 10.2.2, we do expect there to be impacts to Southern Resident killer whale prey species (i.e., ESA-listed Chinook, chum, and Coho). We expect those impacts to fish to be in the form of behavioral disturbance, TTS, and injury, but no mortality. In waters over the continental shelf, where we expect the most likely occurrence of fish prey species, the proposed action will take place over the course of about 10.5 days. After the survey has ended, we expect that fish will return to normal behavior in the action area. The overall short duration of the proposed action in an area where it would be most likely to impact prey species is not expected to rise to a level that would impact the prey PBF to such a degree as to cause significant alteration.

The third PBF concerns inter-area passage conditions for Southern Resident killer whales. The proposed action will take place throughout the proposed critical habitat. Based on density data provided by the Navy (2020), we expect that Southern Resident killer whales will be more likely to occur closer to shore, in areas that have been excluded from the action area. While the presence of the vessels and the proposed seismic activity may impact the Southern Resident killer whales, we are expecting an overall low amount of exposure for Southern Resident killer whales. Based on the size of the action area relative to the proposed critical habitat, Southern Resident killer whales should be able maneuver away from the vessel. Furthermore, the action is of an overall short duration in areas where we expect Southern Resident killer whales most likely to occur (e.g., off the coasts of Washington and Vancouver Island).

The effects of all other stressors analyzed, including vessel traffic and sound associated with the proposed seismic activities, on the essential PBFs were found to be insignificant and not likely to reduce the conservation value of proposed critical habitat. We conclude that the proposed action may affect, but is not likely to adversely affect Southern Resident killer whale proposed coastal critical habitat. We further evaluate the effects of seismic survey acoustic sources later; see Section 10.

7.2.6.2 Puget Sound/Georgia Basin DPS of Boccaccio, Canary Rockfish, and Yelloweye Rockfish Designated Critical Habitat

Critical habitat for the Puget Sound/Georgia Basin DPS of boccaccio, canary rockfish, and yelloweye rockfish was finalized in 2014 (79 FR 68041). Rockfish and boccaccio critical habitat is spread amongst five interconnected, biogeographic basins (San Juan/Strait of Juan de Fuca basin, Main basin, Whidbey basin, South Puget Sound, and Hood Canal) based upon presence and distribution of adult and juvenile rockfish and bocaccio, geographic conditions, and habitat features (Figure 5).

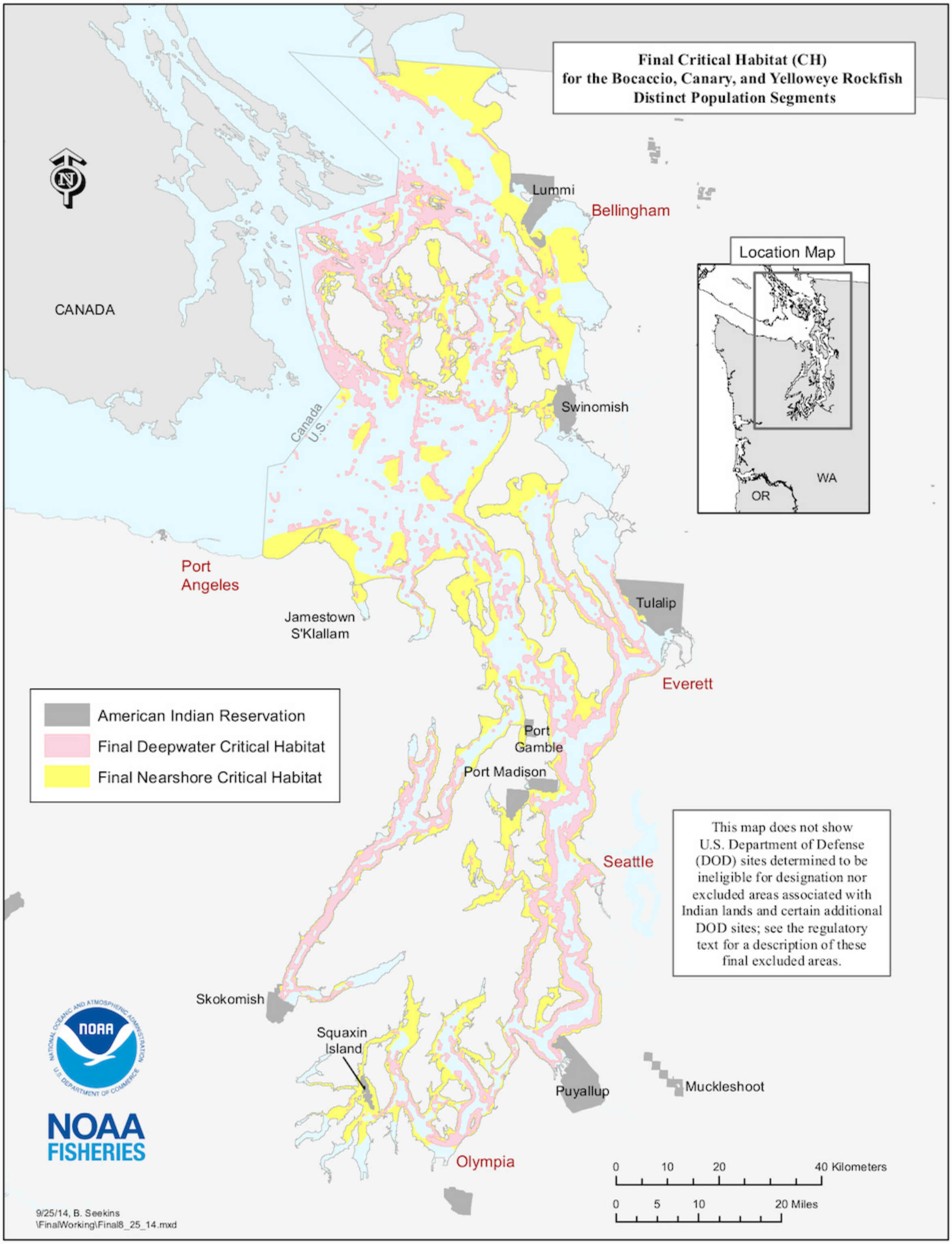

Figure 5. Designated Critical Habitat for ESA-listed Rockfishes.

Juvenile boccaccio settlement habitats located in the nearshore with substrates such as sand, rock and/or cobble compositions that also support kelp are essential for conservation because these features enable forage opportunities and refuge from predators and enable behavioral and physiological changes needed for juveniles to occupy deeper adult habitats (82 FR 7711). The PBFs for juvenile boccaccio in nearshore habitat are: (i) Quantity, quality, and availability of prey species to support individual growth, survival, and feeding opportunities; and (ii) Water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities.

Benthic habitats and sites deeper than 30 meters that possess or are adjacent to areas of complex bathymetry consisting of rock and or highly rugose habitat are essential to conservation because these features support growth, survival, reproduction, and feeding opportunities by providing the structure for adult bocaccio to avoid predation, seek food and persist for decades (82 FR 7711). PBFs for adult bocaccio in deepwater habitat include the two above for juvenile bocaccio related to prey and water quality, as well as the following: (iii) the type and amount of structure and rugosity that supports feeding opportunities and predator avoidance.

Specific threats to boccaccio critical habitat include degradation of rocky habitat, loss of eelgrass and kelp, introduction of non-native species that modify habitat, and degradation of water quality.

The only stressors associated with the proposed action that would occur in the designated critical habitat would be those associated with vessel traffic while the research vessels transit back to port in Seattle. These would include noise associated with vessel operation, pollution from the vessel, and the visual disturbance created by the vessel.

The vessel transit associated with the proposed action will not alter prey quantity, quality, or availability or water quality. The noise, disturbance, and pollution potentially caused by the vessel during transit was evaluated in the previous sections, and found to be insignificant or discountable, respectively. The vessel transit will also not impact any benthic habitats, as the vessel will not anchor, and the likelihood of the vessel running aground is so remote as to be discountable. The effects of these stressors on the PBFs are not likely to reduce the conservation value of the critical habitat, and we conclude that the proposed action may affect, but is not likely to adversely affect designated critical habitat for Puget Sound/Georgia Basin DPS of boccaccio, canary rockfish, and yelloweye rockfish.

7.2.6.3 Humpback Whale Central America and Mexico Distinct Population Segment Proposed Critical Habitat

On October 9, 2019, NMFS proposed critical habitat for three distinct population segments of humpback whale on the U.S. West Coast: Central America, Mexico, and Western North Pacific DPSs. On April 21, 2021, the final rule (86 FR 21082) designating critical habitat for Central America, Mexico, and Western North Pacific DPS humpback whales was published. The designated critical habitat for the Western North Pacific DPS is exclusively in the waters of Alaska, outside of the action area for the proposed action. As such, it will not be discussed here.

The PBF for both the Mexico and Central America DPS critical habitat is prey species, primarily euphausiids and small pelagic schooling fishes of sufficient quality, abundance, and accessibility within humpback whale feeding areas to support feeding and population growth.

For the Central America DPS, the designated critical habitat includes marine waters in Washington, Oregon, and California (Figure 6). Designated critical habitat that falls within the action area are in Washington and Oregon. In Washington, the designated critical habitat nearshore boundary is defined by the 50-meter isobath, and the offshore boundary is defined by the 1,200-meter isobath relative to mean lower low water. Critical habitat also includes waters within the U.S. portion of the Strait of Juan de Fuca to an eastern boundary line at Angeles Point at 123°33′ W. In Oregon, the designated critical habitat nearshore boundary is defined by the 50-meter isobath. The offshore boundary is defined by the 1,200-meter isobath relative to mean lower low water; except, in areas off Oregon south of 42°10′, the offshore boundary is defined by the 2,000-meter isobath.

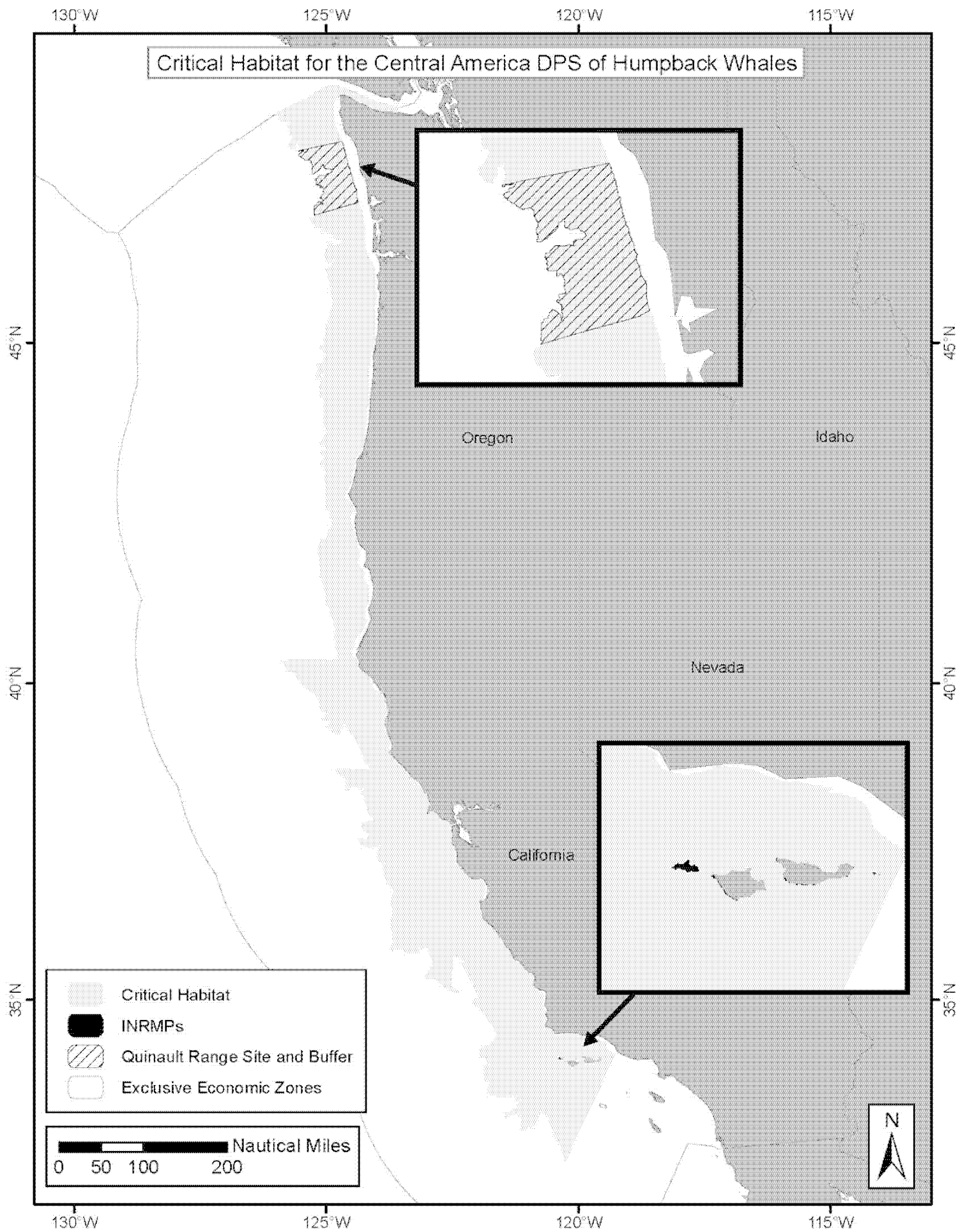

Figure 6. Designated critical habitat for the Central America distinct population segment of humpback whales. The Department of Defense areas subject to an Integrated Natural Resources Management Plan (INRMPs) and the Quinault Range Site are also depicted.

For the Mexico DPS, the designated critical habitat includes marine waters in Washington, Oregon, California, and Alaska (Figure 7). Only the areas proposed for designation in Washington and Oregon fall within the action area.

In Washington, the nearshore boundary is defined by the 50-meter isobath, and the offshore boundary is defined by the 1,200-meter isobath relative to mean lower low water. Critical habitat also includes waters within the U.S. portion of the Strait of Juan de Fuca to an eastern boundary line at Angeles Point at 123°33′ W.

In Oregon, the nearshore boundary is defined by the 50-meter isobath. The offshore boundary is defined by the 1,200-meter isobath relative to mean lower low water; except, in areas off Oregon south of 42°10′, the offshore boundary is defined by the 2,000-meter isobath.

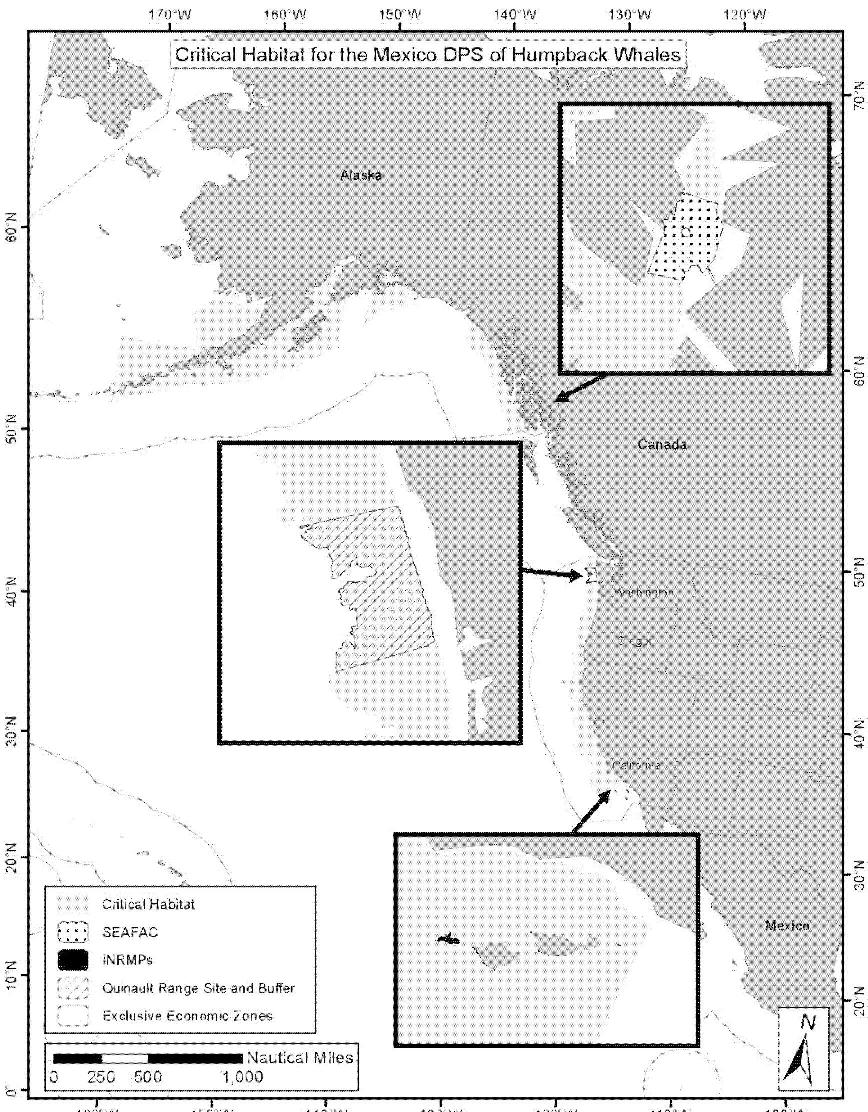

Figure 7. Designated critical habitat for Mexico distinct population segment of humpback whales. The Navy's Southeast Alaska Acoustic Measurement Facility (SEAFAC) and Department of Defense areas subject to an Integrated Natural Resources Management Plan (INRMPs), and the Quinault Range Site are also depicted.

The components of the proposed action that may impact the Mexico and Central America DPS humpback whale proposed critical habitat would be the sound from the airgun array affecting the occurrence of euphausiids and small pelagic schooling fishes. The disturbance caused by placement of ocean bottom seismometers (falling to the ocean floor) and nodes (placed by ROV) may also temporarily disperse fish. While the sound from airguns and the placement of the ocean bottom seismometers could disperse humpback whale prey, the impact is anticipated to be temporary and of short duration (only occurring during ensonification or activity duration, with a return to normal conditions a few days at most after the activity has ceased in an area) and of negligible magnitude (in terms of area size and proportion of available forage). The designated critical habitat is over 166,000 square kilometers along the entire U.S. West Coast (out to 1,200 meters deep, or 2,000 meters deep), compared to the 79,591 square kilometers for the entire ensonified area for the survey, in water depths over 6,000 meters deep. As a result, the effects of noise associated with the proposed seismic survey are anticipated to be insignificant. Therefore, the proposed action may affect, but is not likely to adversely affect Mexico and Central America DPS humpback whale critical habitat.

7.2.6.4 Steller Sea Lion Western Distinct Population Segment Critical Habitat

In 1997, NMFS designated critical habitat for the Steller sea lion. The Steller sea lion eastern DPS was delisted on November 4, 2013 (78 FR 66139); therefore, this DPS will not be considered in this opinion. However, this change in listing status does not affect the designated critical habitat for Steller sea lions (58 FR 45269), because "removing the eastern DPS from the List of Endangered and Threatened Wildlife does not remove or modify that designation" (78 FR 66162). Steller sea lion designated critical habitat remains in place until a separate rulemaking amends the designation.

The critical habitat includes specific rookeries, haulouts, and associated areas, as well as three foraging areas that are considered to be essential for the health, continued survival, and recovery of the species. The three areas of Steller sea lion critical habitat are located in Alaska, Oregon and California; only the critical habitat areas in Oregon fall within the action area. Within the action area, critical habitat is located on islands off the coast of Oregon (Long Brown and Seal Rocks, and Pyramid Rock).

In Oregon, major Steller sea lion rookeries and associated air and aquatic zones are designated as critical habitat. Critical habitat includes an air zone extending 3,000 feet (0.9 kilometers) above rookery areas historically occupied by sea lions. Critical habitat also includes an aquatic zone extending 3,000 feet (0.9 kilometers) seaward. These sites are located near Steller sea lion abundance centers and include important foraging areas, large concentrations of prey, and host large commercial fisheries that often interact with the species.

The PBFs identified for the aquatic areas of Steller sea lion designated critical habitat that occur within the action area are those that support foraging, such as adequate prey resources and available foraging habitat (58 FR 45269). While Steller sea lions do rest in aquatic habitat, there was insufficient information available at the time critical habitat was designated to include aquatic resting sites as part of the critical habitat designation (58 FR 45269).

The R/V *Oceanus* will not place ocean bottom seismometers or nodes in or near Steller sea lion critical habitat in Oregon, so that aspect of the proposed action will not affect critical habitat. The seismic survey tracklines will be about 9 and 13 kilometers away from the two Oregon units of Steller sea lion critical habitat. The extent of the ensonified area would reach the critical habitat. However, the R/V *Marcus G. Langseth* will travel at a speed of 4.2 knots (7.8 kilometers per hour during the survey, meaning the critical habitat units will only be exposed to sound from the seismic survey activity for a few hours.

Therefore, the short duration of the potential exposure, and the expected minor effects to prey species, lead us to conclude that the seismic survey activities would result in insignificant effects to designated Steller sea lion critical habitat. Therefore, the proposed action may affect, but is not likely to adversely affect Steller sea lion critical habitat.

7.2.6.5 Leatherback Turtle Critical Habitat

In 2012, NMFS revised designated critical habitat for the leatherback turtle by designating additional areas within the Pacific Ocean (Figure 6). This designation includes approximately 43,798 square kilometers (16,910 square miles) stretching along the California coast from Point Arena to Point Arguello east of the 3,000 meter (9,842.4 feet) depth contour; and 64,760 square kilometers (25,004 square miles) stretching from Cape Flattery, Washington to Cape Blanco, Oregon east of the 2,000 meter (6,561.7 feet) depth contour. The designated areas comprise approximately 108,558 square kilometers (41,914 square miles) of marine habitat and include waters from the ocean surface down to a maximum depth of 80 meters (262 feet). NMFS has identified one PBF for the conservation of leatherback turtles in marine waters off the U.S. West Coast that includes the occurrence of prey species, primarily scyphomedusae (i.e., jellyfish) of the order Semaeostomeae (e.g., *Chrysaora*, *Aurelia*, *Phacellophora*, and *Cyanea*), of sufficient condition, distribution, diversity, abundance, and density necessary to support individual as well as population growth, reproduction, and development of leatherback turtles (77 FR 4170).

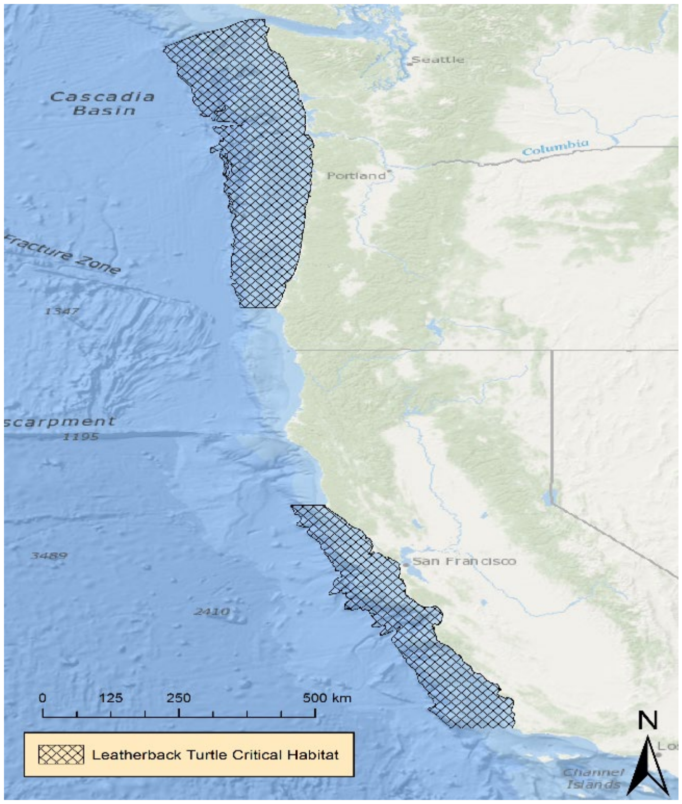

Figure 8. Map depicting leatherback turtle designated critical habitat along the United States Pacific Coast.

The components of the proposed action that may impact the leatherback sea turtle critical habitat would be the sound from the airgun array affecting the occurrence of jellyfish. While the sound could disperse leatherback prey, the impact is anticipated to be temporary and of short duration (only occurring during ensonification or activity duration, with a return to normal conditions a few days at most after the activity has ceased in an area) and of negligible magnitude (in terms of area size and proportion of available forage), and we consider those impacts to be insignificant. Therefore, proposed action may affect, but is not likely to adversely affect leatherback sea turtle critical habitat.

7.2.6.6 Green Sturgeon Southern Distinct Population Segment Critical Habitat

In 2009, NMFS designated critical habitat for the Southern DPS of green sturgeon. Specific areas include coastal U.S. marine waters within 109.7 meters (359.9 feet) depth from Monterey Bay, California (including Monterey Bay), north to Cape Flattery, Washington, including the Strait of Juan de Fuca, Washington, to its U.S. boundary; and certain coastal bays and estuaries in (Figure 9). NMFS designated approximately 2,323 square kilometers (11,421 square miles) of marine habitat as critical habitat for Southern DPS of green sturgeon. The PBFs essential for Southern DPS of green sturgeon include nearshore coastal marine areas that provide sufficient food resources, substrate type suitable for egg deposition, and development, water flow, water quality, migratory corridors, depth (greater than or equal to 5 meters [16.4 feet]), and sediment quality.

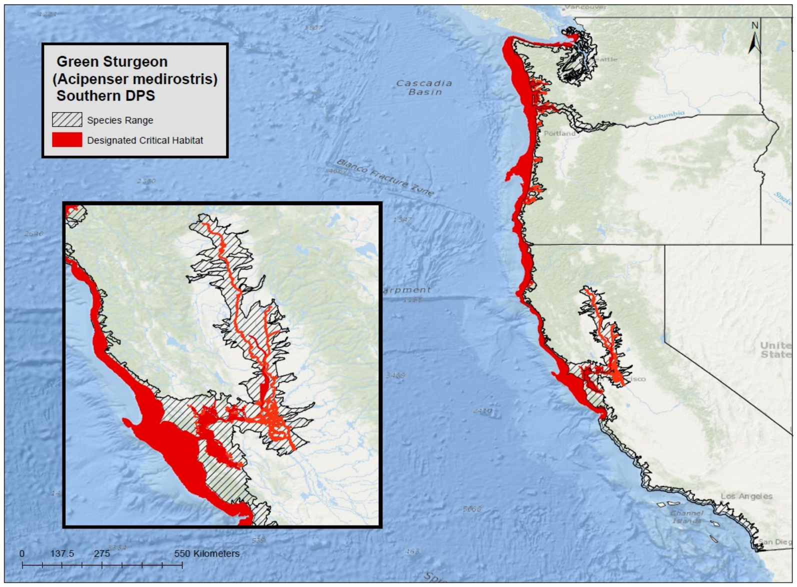

Figure 9. Map of geographic range (within the contiguous United States) and designated critical habitat for Southern distinct population segment of green sturgeon. Sacramento River basin inset.

The proposed activities do not occur in freshwater or estuarine habitats and will not affect critical habitat designated in these areas. Marine areas of critical habitat overlap with portions of the action area. The critical habitat's PBFs in marine habitat include migratory corridor, water quality, and food resources. No impediment of migration corridors would be expected to occur. The entire proposed action will take place over about 37 days, and the amount of time that the action will overlap with green sturgeon critical habitat is a few days. In the event acoustic stressors (or any other stressors) affect forage species, the impact is anticipated to be temporary and of short duration (only occurring during ensonification or activity duration) and of negligible magnitude (in terms of area size and proportion of available forage), and we consider those impacts to be insignificant. Therefore, we believe the proposed action may affect, but is not likely to adversely affect green sturgeon critical habitat.

7.2.6.7 Eulachon Southern Distinct Population Segment Critical Habitat

In 2011, NMFS designated critical habitat (76 FR 65324) for the Southern DPS of eulachon. Sixteen areas were designated in the states of Washington, Oregon, and California (Figure 10). The designated areas are a combination of freshwater creeks and rivers and their associated estuaries, comprising approximately 539 kilometers (335 miles) of habitat.

The PBFs essential to the conservation of the DPS include:

- Freshwater spawning and incubation sites with water flow, quality and temperature conditions and substrate supporting spawning and incubation, and with migratory access for adults and juveniles.
- Freshwater and estuarine migration corridors associated with spawning and incubation sites that are free of obstruction and with water flow, quality and temperature conditions

supporting larval and adult mobility, and with abundant prey items supporting larval feeding after the yok sac is depleted.

- Nearshore and offshore marine foraging habitat with water quality and available prey, supporting juveniles and adult survival. The components of the nearshore and offshore marine foraging essential feature include prey items in concentrations that support growth and reproductive development for juveniles and adults, and water quality with adequate dissolved oxygen, temperature, and lack of contaminants.

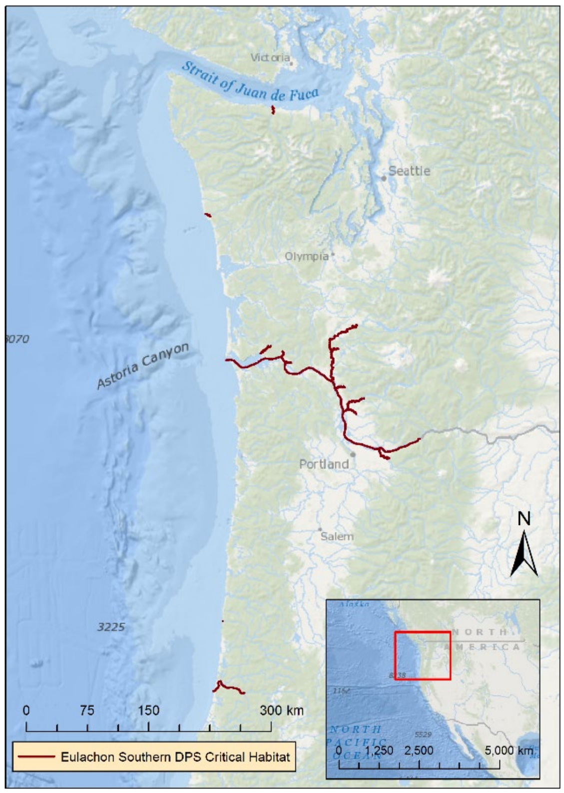

Figure 10. Map of designated critical habitat for the threatened Southern distinct population segment of eulachon; nearshore and marine areas of critical habitat not depicted.

The proposed action will take place off the coasts of Oregon and Washington. The ensonified area will not impact the nearshore and marine foraging areas off Washington, because the survey tracklines are far enough away from the coast, seaward of the 100-meter isobath. The ensonified area off Oregon may extend into the nearshore and marine foraging areas of critical habitat, because the survey lines, and resulting ensonified areas, extend closer to shore. The nearshore and marine foraging areas are within the proposed action area. The proposed action will involve vessel transit, placement of ocean bottom seismometers and ocean bottom nodes, seismic airgun activity, and operation of a multibeam echosounder and subbottom profiler, which will not alter water quality (other than the possibility of temporary and limited sediment resuspension as nodes or seismometers are dropped to the seaflood) or introduce contaminants into the marine environment; the marine debris (i.e., anchors from the oceanbottom seismometers) was analyzed and found to be insignificant (see 6.1 for further discussion). The sound produced by the airgun array may affect prey species like aquatic invertebrates and fishes. In the event acoustic stressors (or any other stressors) affect forage species, the impact is anticipated to be temporary and of short duration (only occurring during ensonification or activity duration, which would amount to a few days when the survey is off the coast of Oregon) and of negligible magnitude (in terms of area size and proportion of available forage). We consider these impacts to be insignificant, and conclude that the proposed action may affect, but is not likely to adversely affect Southern DPS eulachon critical habitat.

8 Species and Critical Habitat Likely to be Adversely Affected

This opinion examines the status of ESA-listed species and designated critical habitat that may be adversely affected by the proposed action.

The evaluation of adverse effects in this opinion begins by summarizing the biology and ecology of those species that are likely to be adversely affected and what is known about their life histories in the action area. The status is determined by the level of risk that the ESA-listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This helps to inform the description of the species' current "reproduction, numbers, or distribution," which is part of the jeopardy determination as described in 50 C.F.R. §402.02. More detailed information on the status and trends of these ESA-listed species, and their biology and ecology can be found in the listing regulations and critical habitat designations published in the Federal Register, status reviews, recovery plans, and on this NMFS Web site: https://www.fisheries.noaa.gov/find-species.

One factor affecting the rangewide status of marine mammals, sea turtles, and aquatic habitat at large is climate change. Climate change will be discussed in the *Environmental Baseline* section (Section 9).

8.1 Blue Whale

The blue whale is a widely distributed baleen whale found in all major oceans. Blue whales are the largest animal on earth and distinguishable from other whales by a long body and comparatively slender shape, a broad, flat "rostrum" when viewed from above, proportionally smaller dorsal fin, and a mottled gray color that appears light blue when seen through the water. Most experts recognize at least three subspecies of blue whale, *B. m. musculus*, which occurs in the Northern Hemisphere, *B. m. intermedia*, which occurs in the Southern Ocean, and *B. m. brevicauda*, a pygmy species found in the Indian Ocean and South Pacific Ocean. The blue whale was originally listed as endangered on December 2, 1970.

Information available from the recovery plan (NMFS 1998), recent stock assessment reports (Carretta 2019a; Carretta 2019b), and recent scientific publications were used to summarize the life history, population dynamics, and status of the species as follows.

8.1.1 Life History

The average life span of blue whales is 80 to 90 years. They have a gestation period of ten to 12 months, and calves nurse for six to seven months. Blue whales reach sexual maturity between 5 and 15 years of age with an average calving interval of two to three years. They winter at low latitudes, where they mate, calve and nurse, and summer at high latitudes, where they feed. In the northeast Pacific, blue whales overwinter along the Pacific Coast of Baja California, and the upwelling area known as the Costa Rica Thermal Dome, but they may use other areas as well (Nichol 2011). Blue whales forage almost exclusively on krill and can eat approximately 3,600 kilograms (7,936.6 pounds) daily. Feeding aggregations are often found at the continental shelf edge, where upwelling produces concentrations of krill at depths of 90 to 120 meters (295.3 to 393.7 feet).

8.1.2 Population Dynamics

The global, pre-exploitation estimate for blue whales is approximately 181,200 (IWC 2007b). Current estimates indicate approximately 5,000 to 12,000 blue whales globally (IWC 2007b). Blue whales are separated into populations by ocean basin in the North Atlantic Ocean, North Pacific Ocean, and Southern Hemisphere. There are three stocks of blue whales designated in United States waters: the Eastern North Pacific Ocean, Central North Pacific Ocean, and Western North Atlantic Ocean. Due to the location of the action, the Eastern North Pacific stock of blue whales is most likely to be in the action area. The minimum population size for eastern North Pacific Ocean blue whales is 1,050; the more recent abundance estimate is 1,496 whales (Carretta 2019a).

Current estimates indicate a growth rate of just under three percent per year for the eastern North Pacific stock (Calambokidis 2009).

Little genetic data exist on blue whales globally. Data on genetic diversity of blue whales in the Northern Hemisphere are currently unavailable. However, genetic diversity information for similar cetacean population sizes can be applied. Stocks that have a total population size of 2,000 to 2,500 individuals or greater provide for maintenance of genetic diversity resulting in long-term persistence and protection from substantial environmental variance and catastrophes. Stocks that have a total population of 500 individuals or less may be at a greater risk of extinction due to genetic risks resulting from inbreeding. Stock population at low densities (less than 100) are more likely to suffer from the 'Allee' effect, where inbreeding and the heightened difficulty of finding mates reduces the population growth rate in proportion with reducing density.

In general, distribution is driven largely by food requirements; blue whales are more likely to occur in waters with dense concentrations of their primary food source, krill. While they can be found in coastal waters, they are thought to prefer waters further offshore. In Canadian Pacific waters, blue whale habitat includes the continental shelf break, continental slope, and offshore waters beyond the shelf break (Canada 2017). Off California, they are associated with areas of upwelling off the continental slope, likely due to high concentrations of zooplankton there

(Nichol 2011). Data from satellite telemetry research indicate that blue whales in U.S. West Coast waters spend about five months outside the U.S. EEZ, from November to March (Hazen et al. 2017). In the North Pacific Ocean, blue whales range from Kamchatka to southern Japan in the west and from the Gulf of Alaska and California to Costa Rica in the east. They primarily occur off the Aleutian Islands and the Bering Sea.

8.1.3 Vocalization and Hearing

Blue whale vocalizations tend to be long (greater than 20 seconds), low frequency (less than 100 hertz) signals (Thomson and Richardson 1995a), with a range of 12 to 400 hertz and dominant energy in the infrasonic range of 12 to 25 hertz (McDonald et al. 1995; Mcdonald et al. 2001; Mellinger and Clark 2003). Vocalizations are predominantly songs and calls.

Calls are short-duration sounds (two to five seconds) that are transient and frequency-modulated, having a higher frequency range and shorter duration than song units and often sweeping down in frequency (20 to 80 hertz), with seasonally variable occurrence. Blue whale calls have high acoustic energy, with reports of source levels ranging from 180 to 195 dB re: 1 μPa at 1 meter (Cummings and Thompson 1971; Aburto et al. 1997; Mcdonald et al. 2001; Clark and Gagnon 2004; Berchok et al. 2006; Samaran et al. 2010). Calling rates of blue whales tend to vary based on feeding behavior. For example, blue whales make seasonal migrations to areas of high productivity to feed, and vocalize less at the feeding grounds then during migration (Burtenshaw et al. 2004a). Stafford et al. (2005) recorded the highest calling rates when blue whale prey was closest to the surface during its vertical migration. Wiggins et al. (2005) reported the same trend of reduced vocalization during daytime foraging followed by an increase at dusk as prey moved up into the water column and dispersed. Oleson et al. (2007c) reported higher calling rates in shallow diving (less than 30 meters [98.4 feet] whales), while deeper diving whales (greater than 50 meters [154 feet]) were likely feeding and calling less.

Although general characteristics of blue whale calls are shared in distinct regions (Thompson et al. 1996; Mcdonald et al. 2001; Mellinger and Clark 2003; Rankin et al. 2005), some variability appears to exist among different geographic areas (Rivers 1997). Sounds in the North Atlantic Ocean have been confirmed to have different characteristics (i.e., frequency, duration, and repetition) than those recorded in other parts of the world (Mellinger and Clark 2003; Berchok et al. 2006; Samaran et al. 2010). Clear differences in call structure suggestive of separate populations for the western and eastern regions of the North Pacific Ocean have also been reported (Stafford et al. 2001); however, some overlap in calls from the geographically distinct regions have been observed, indicating that the whales may have the ability to mimic calls (Stafford and Moore 2005). In Southern California, blue whales produce three known call types: Type A, B, and D. B calls are stereotypic of blue whale population found in the eastern North Pacific (McDonald et al. 2006) and are produced exclusively by males and associated with mating behavior (Oleson et al. 2007a). These calls have long durations (20 seconds) and low frequencies (10 to 100 hertz); they are produced either as repetitive sequences (song) or as singular calls. The B call has a set of harmonic tonals, and may be paired with a pulsed Type A call. D calls are produced in highest numbers during the late spring and early summer and in diminished numbers during the fall, when A-B song dominates blue whale calling (Oleson et al. 2007c; Hildebrand et al. 2011; Hildebrand et al. 2012).

Blue whale songs consist of repetitively patterned vocalizations produced over time spans of minutes to hours or even days (Cummings and Thompson 1971; Mcdonald et al. 2001). The songs are divided into pulsed/tonal units, which are continuous segments of sound, and phrases, repeated in combinations of one to five units (Payne and Mcvay 1971; Mellinger and Clark 2003). Songs can be detected for hundreds, and even thousands of kilometers (Stafford et al. 1998), and have only been attributed to males (Mcdonald et al. 2001; Oleson et al. 2007a). Worldwide, songs are showing a downward shift in frequency (McDonald et al. 2009). For example, a comparison of recording from November 2003 and November 1964 and 1965 reveals a long-term shift in the frequency of blue whale calling near San Nicolas Island. In 2003, the spectral energy peak was 16 hertz compared to approximately 22.5 hertz in 1964 and 1965, illustrating a more than 30 percent shift in call frequency over four decades (McDonald et al. 2006). McDonald et al. (2009) observed a 31 percent downward frequency shift in blue whale calls off the coast of California, and also noted lower frequencies in seven of the world's ten known blue whale songs originating in the Atlantic, Pacific, Southern, and Indian Oceans. Many possible explanations for the shifts exist but none have emerged as the probable cause.

As with other baleen whale vocalizations, blue whale vocalization function is unknown, although numerous hypotheses exist (maintaining spacing between individuals, recognition, socialization, navigation, contextual information transmission, and location of prey resources; (Payne and Webb. 1971; Thompson et al. 1992; Edds-Walton 1997; Oleson et al. 2007b). Intense bouts of long, patterned sounds are common from fall through spring in low latitudes, but these also occur less frequently while in summer high-latitude feeding areas. Short, rapid sequences of 30 to 90 hertz calls are associated with socialization and may be displays by males based upon call seasonality and structure. The low frequency sounds produced by blue whales can, in theory, travel long distances, and it is possible that such long distance communication occurs (Payne and Webb. 1971; Edds-Walton 1997). The long-range sounds may also be used for echolocation in orientation or navigation (Tyack 1999).

Direct studies of blue whale hearing have not been conducted, but it is assumed that blue whales can hear the same frequencies that they produce (low frequency) and are likely most sensitive to this frequency range (Richardson et al. 1995c; Ketten 1997). Based on vocalizations and anatomy, blue whales are assumed to predominantly hear low-frequency sounds below 400 hertz (Croll et al. 2001; Stafford and Moore 2005; Oleson et al. 2007c). In terms of functional hearing capability, blue whales belong to the low frequency group, which have a hearing range of 7 hertz to 35 kilohertz (NOAA 2018).

8.1.4 Status

The blue whale is endangered as a result of past commercial whaling. In the eastern North Pacific Ocean, about 3,411 blue whales were killed between 1905 and 1971 (Monnahan et al.

2014). According to historical whaling records from five whaling stations in British Columbia, 1,398 blue whales were killed between 1908 and 1967 (Gregr et al. 2000). Commercial whaling no longer occurs, but blue whales are affected by anthropogenic noise, threatened by ship strikes, entanglement in fishing gear, pollution, harassment due to whale watching, and reduced prey abundance and habitat degradation due to climate change. Because populations appear to be increasing in size, the species appears to be somewhat resilient to current threats; however, the species has not recovered to pre-exploitation levels.

8.1.5 Critical Habitat

No critical habitat has been designated for the blue whale.

8.1.6 Recovery Goals

See the 1998 Final Recovery Plan for the Blue Whale for complete downlisting/delisting criteria for each of the following recovery goals:

1. Determine stock structure of blue whale populations occurring in U.S. waters and elsewhere.
2. Estimate the size and monitor trends in abundance of blue whale populations.
3. Identify and protect habitat essential to the survival and recovery of blue whale populations.
4. Reduce or eliminate human-caused injury and mortality of blue whales.
5. Minimize detrimental effects of directed vessel interactions with blue whales.
6. Maximize efforts to acquire scientific information from dead, stranded, and entangled blue whales.
7. Coordinate state, federal, and international efforts to implement recovery actions for blue whales.
8. Establish criteria for deciding whether to delist or downlist blue whales.

8.2 Fin Whale

The fin whale is a large, widely distributed baleen whale found in all major oceans and comprised of three subspecies: *B. p. physalus* in the Northern Hemisphere, and *B. p. quoyi* and *B. p. patachaonica* (a pygmy form) in the Southern Hemisphere. Within the action area, fin whales occur year round off the coasts of Oregon and Washington (Carretta 2019b), as well as in the waters of British Columbia throughout the year (DFO 2017).

Fin whales are distinguishable from other whales by a sleek, streamlined body, with a V-shaped head, a tall falcate dorsal fin, and a distinctive color pattern of a black or dark brownish-gray body and sides with a white ventral surface. The lower jaw is gray or black on the left side and creamy white on the right side. The fin whale was originally listed as endangered on December 2, 1970.

Information available from the recovery plan (NMFS 2010b), recent stock assessment reports (Carretta 2019a; Carretta 2019b), and status review (NMFS 2011e) were used to summarize the life history, population dynamics and status of the species as follows.

8.2.1 Life History

Fin whales can live, on average, 80 to 90 years. They have a gestation period of less than one year, and calves nurse for six to seven months. Data from historical whaling records in Hecate Strait and Queen Charlotte Sound indicate that most births in the region occurred between mid-November and mid-March, with a peak in January (DFO 2017). Sexual maturity is reached between six and ten years of age with an average calving interval of two to three years. They mostly inhabit deep, offshore waters of all major oceans. They winter at low latitudes, where they calve and nurse, and summer at high latitudes, where they feed, although some fin whales appear to be residential to certain areas. Acoustic recording data in British Columbia indicate that fin whales are present year-round (Koot 2015). Due to the detection of calling males from November through January, researchers assume that breeding occurs in Canadian Pacific waters in Hecate Strait and Queen Charlotte Sound during that time of year (DFO 2017). Fin whales eat pelagic crustaceans (mainly euphausiids or krill) and schooling fish such as capelin, herring, and sand lice. There is a presumed feeding area along the Juan de Fuca Ridge off northern Washington, based on rates of fin whale calls in the area from fall through February (Soule and Wilcock 2013; Muto et al. 2019).

8.2.2 Population Dynamics

The following is a discussion of the species' population and its variance over time. This section includes abundance, population growth rate, genetic diversity, and spatial distribution as it relates to the fin whale.

The pre-exploitation estimate for the fin whale population in the North Pacific Ocean was 42,000 to 45,000. The North Pacific population of fin whales was reduced to 13,620 to 18,680 by 1973 (Ohsumi and Wada 1974). There are three stocks in United States Pacific Ocean waters: Northeast Pacific [minimum 1,368 individuals], Hawaii (approximately 58 individuals [N_{min}=27]) and California/Oregon/Washington (approximately 9,029 [N_{min}=8,127] individuals) (Nadeem et al. 2016). According to whaling records from Canadian Pacific waters, at least 7,605 fin whales were killed between 1908 to 1967 (Gregr et al. 2000).

The best current abundance estimate for fin whales in California, Oregon, and Washington waters out to 300 nautical miles is 9,029 (CV=0.12) (Nadeem et al. 2016); the minimum population estimate is 8,127 individuals (Carretta 2019b). Based on a photo-identification mark-recapture model using data from the Hecate Strait and Queen Charlotte Sound in British Columbia, fin whale abundance for that area was estimated at 405 individuals (CV=0.6, 95% CI=363-469) (Nichol 2018). An overall fin whale population trend in the U.S. Pacific has not been established, but there is evidence that there has been increasing rates in the recent past in different parts of the region. From 1991 to 2014, the estimated average rate of increase for

California, Oregon, and Washington waters was 7.5 percent, with the caveat that is unknown how much of that rate could be attributed to immigration rather than birth and death processes (Carretta 2019b).

Archer et al. (2013) examined the genetic structure and diversity of fin whales globally. Full sequencing of the mitochondrial DNA genome for 154 fin whales sampled in the North Atlantic Ocean, North Pacific Ocean, and Southern Hemisphere, resulted in 136 haplotypes, none of which were shared among ocean basins suggesting differentiation at least at this geographic scale. However, North Atlantic Ocean fin whales appear to be more closely related to the Southern Hemisphere population, as compared to fin whales in the North Pacific Ocean, which may indicate a revision of the subspecies delineations is warranted. Results of a later single-nucleotide polymorphism analysis indicate that distinct mitogenome matrilines in the North Pacific are interbreeding (Archer et al. 2019). Generally speaking, haplotype diversity was found to be high both within oceans basins, and across, with the greatest diversity found in North Pacific fin whales (Archer et al. 2019). Such high genetic diversity and lack of differentiation within ocean basins may indicate that despite some populations having small abundance estimates, the species may persist long-term and be somewhat protected from substantial environmental variance and catastrophes.

Within the action area, fin whales are present year-round off the coasts of Oregon, Washington, and Vancouver Island. The availability of prey, sand lice in particular, is thought to have had a strong influence on the distribution and movements of fin whales.

8.2.3 Vocalization and Hearing

Fin whales produce a variety of low frequency sounds in the 10 to 200 hertz range (Watkins 1981; Watkins et al. 1987; Edds 1988; Thompson et al. 1992). Typical vocalizations are long, patterned pulses of short duration (0.5 to two seconds) in the 18 to 35 hertz range, but only males are known to produce these (Patterson and Hamilton 1964; Clark et al. 2002). The most typically recorded call is a 20 hertz pulse lasting about one second, and reaching source levels of 189 ±4 dB re: 1 μPa at 1 meter (Watkins 1981; Watkins et al. 1987; Edds 1988; Richardson et al. 1995c; Charif et al. 2002; Clark et al. 2002; Sirovic et al. 2007). These pulses frequently occur in long sequenced patterns, are down swept (e.g., 23 to 18 hertz), and can be repeated over the course of many hours (Watkins et al. 1987). In temperate waters, intense bouts of these patterned sounds are very common from fall through spring, but also occur to a lesser extent during the summer in high latitude feeding areas (Clark and Charif 1998). Richardson et al. (1995c) reported this call occurring in short series during spring, summer, and fall, and in repeated stereotyped patterns in winter. The seasonality and stereotype nature of these vocal sequences suggest that they are male reproductive displays (Watkins 1981; Watkins et al. 1987); a notion further supported by data linking these vocalizations to male fin whales only (Croll et al. 2002). In Southern California, the 20 hertz pulses are the dominant fin whale call type associated both with call-counter-call between multiple animals and with singing (Navy 2010; U.S. Navy 2012). An additional fin whale sound, the 40 hertz call described by Watkins (1981), was also frequently recorded, although these calls are not as common as the 20 hertz fin whale pulses. Seasonality of the 40 hertz calls differed from the 20 hertz calls, since 40 hertz calls were more prominent in the spring, as observed at other sites across the northeast Pacific Ocean (Sirovic et al. 2012). Source levels of Eastern Pacific Ocean fin whale 20 hertz calls has been reported as 189 ± 5.8 dB re: 1 μPa at 1 meter (Weirathmueller et al. 2013). Some researchers have also recorded moans of 14 to 118 hertz, with a dominant frequency of 20 hertz, tonal vocalizations of 34 to 150 hertz, and songs of 17 to 25 hertz (Watkins 1981; Edds 1988; Cummings and Thompson 1994). In general, source levels for fin whale vocalizations are 140 to 200 dB re: 1 μPa at 1 meter (as compiled by Erbe 2002c; see also Clark and Gagnon 2004). The source depth of calling fin whales has been reported to be about 50 meters (164 feet) (Watkins et al. 1987). Although acoustic recordings of fin whales from many diverse regions show close adherence to the typical 20-hertz bandwidth and sequencing when performing these vocalizations, there have been slight differences in the pulse patterns, indicative of some geographic variation (Watkins et al. 1987; Thompson et al. 1992).

Although their function is still in doubt, low frequency fin whale vocalizations travel over long distances and may aid in long distance communication (Payne and Webb. 1971; Edds-Walton 1997). During the breeding season, fin whales produce pulses in a regular repeating pattern, which have been proposed to be mating displays similar to those of humpback whales (Croll et al. 2002). These vocal bouts last for a day or longer (Tyack 1999). Also, it has been suggested that some fin whale sounds may function for long range echolocation of large-scale geographic targets such as seamounts, which might be used for orientation and navigation (Tyack 1999).

Direct studies of fin whale hearing have not been conducted, but it is assumed that fin whales can hear the same frequencies that they produce (low) and are likely most sensitive to this frequency range (Richardson et al. 1995c; Ketten 1997). This suggests fin whales, like other baleen whales, are more likely to have their best hearing capacities at low frequencies, including frequencies lower than those of normal human hearing, rather than mid- to high-frequencies (Ketten 1997). In a study using computer tomography scans of a calf fin whale skull, Cranford and Krysl (2015) found sensitivity to a broad range of frequencies between 10 hertz and 12 kilohertz and a maximum sensitivity to sounds in the 1 to 2 kilohertz range. In terms of functional hearing capability, fin whales belong to the low-frequency group, which have a hearing range of 7 hertz to 35 kilohertz (NOAA 2018).

8.2.4 Status

The fin whale is endangered as a result of past commercial whaling. Prior to commercial whaling, hundreds of thousands of fin whales existed. Fin whales may be killed under "aboriginal subsistence whaling" in Greenland, under Japan's scientific whaling program, and Iceland's formal objection to the International Whaling Commission's ban on commercial whaling. Additional threats include ship strikes, reduced prey availability due to overfishing or climate change, and noise. The species' overall large population size may provide some resilience to current threats, but trends are largely unknown.

8.2.5 Critical Habitat

No critical habitat has been designated for the fin whale.

8.2.6 Recovery Goals

See the 2010 Final Recovery Plan for the fin whale for complete downlisting/delisting criteria for both of the following recovery goals:

1. Achieve sufficient and viable population in all ocean basins.
2. Ensure significant threats are addressed.

8.3 Humpback Whale—Central America and Mexico Distinct Population Segments

The humpback whale is a widely distributed baleen whale found in all major oceans. Humpback whales are distinguishable from other whales by long pectoral fins and are typically dark grey with some areas of white. The humpback whale was originally listed as endangered on December 2, 1970 (35 FR 18319). Since then, NMFS has designated 14 DPSs with four identified as endangered (Cape Verde Islands/Northwest Africa, Western North Pacific, Central America, and Arabian Sea) and one as threatened (Mexico).

Information available from the recovery plan (NMFS 1991), the recent stock assessment report (Carretta 2019b), the status review (Bettridge et al. 2015), and the final listing were used to summarize the life history, population dynamics and status of the species as follows.

8.3.1 Life History

Humpback whales can live, on average, 50 years. They have a gestation period of 11 to 12 months, and calves nurse for one year. Sexual maturity is reached between five to 11 years of age. Every one to five years, females give birth to a single calf, with an average calving interval of two to three years. Humpback whales mostly inhabit coastal and continental shelf waters. They winter at lower latitudes, where they calve and nurse, and summer at high latitudes, where they feed. In British Columbia, the highest numbers of humpback whales are found between May and October, however, individuals are observed throughout the year (Ford 2009). Humpback whales exhibit a wide range of foraging behaviors and feed on a range of prey types, including: small schooling fishes, euphausiids, and other large zooplankton (Bettridge et al. 2015).

8.3.2 Population Dynamics

The following is a discussion of the species' population and its variance over time. This section includes abundance, population growth rate, genetic diversity, and spatial distribution as it relates to the Central America DPS and Mexico DPS of humpback whales.

The global, pre-exploitation estimate for humpback whales is 1,000,000 (Roman and Palumbi 2003). Prior to 1905, whaling records indicate that the humpback whale population in the North Pacific was 15,000 whales. By 1966, whaling had reduced the North Pacific population to about 1,200. In the 2015 status review for humpback whales, the abundance of the Central America DPS was 431 (CV=0.3) and 783 (CV=0.17) individuals (Bettridge et al. 2015); however, this estimate is based on data from 2004 through 2006, and is not considered a reliable estimate of current abundance (Carretta 2019a). A population growth rate is currently unavailable for the Central America DPS and the Mexico DPS of humpback whales. The current abundance of the Mexico DPS is unavailable, but it is thought to be more than 2,000 individuals (Bettridge et al. 2015).

The Canadian Department of Fisheries and Oceans describes the humpback whales in their jurisdictional waters as the Canadian North Pacific population, which ranges from along the west coast of Vancouver, between the borders from Washington to Alaska. The best estimate of this population is 2,145 individuals (Canada 2013).

For humpback whales, DPSs that have a total population size of 2,000 to 2,500 individuals or greater provide for maintenance of genetic diversity resulting in long-term persistence and protection from substantial environmental variance and catastrophes. Distinct population segments that have a total population of 500 individuals or less may be at a greater risk of extinction due to genetic risks resulting from inbreeding. Populations at low densities (less than one hundred) are more likely to suffer from the 'Allee" effect, where inbreeding and the heightened difficulty of finding mates reduces the population growth rate in proportion with reducing density. The Central America DPS has just below 500 individuals and so may be subject to genetic risks due to inbreeding and moderate environmental variance. The Mexico DPS is estimated to have more than 2,000 individuals and thus, should have enough genetic diversity for long-term persistence and protection from substantial environmental variance and catastrophes (Bettridge et al. 2015).

The Central America DPS is composed of humpback whales that breed along the Pacific coast of Costa Rica, Panama, Guatemala, El Salvador, Honduras, and Nicaragua. This DPS feeds almost exclusively offshore of California and Oregon in the eastern Pacific Ocean, with only a few individuals identified at the northern Washington – southern British Columbia feeding grounds.

The Mexico DPS is composed of humpback whales that breed along the Pacific coast of mainland Mexico, and the Revillagigedos Islands, and transit through the Baja California Peninsula coast. This DPS feeds across a broad geographic range from California to the Aleutian Islands, with concentrations in California-Oregon, northern Washington-southern British Columbia, northern and western Gulf of Alaska, and Bering Sea feeding grounds (81 FR 62259).

8.3.3 Vocalization and Hearing

Humpback whale vocalization is much better understood than is hearing. Different sounds are produced that correspond to different functions: feeding, breeding, and other social calls (Dunlop et al. 2008). Males sing complex sounds while in low-latitude breeding areas in a frequency range of 20 hertz to 4 kilohertz with estimated source levels from 144 to 174 dB (Winn et al. 1970b; Richardson et al. 1995f; Au et al. 2000; Frazer and Mercado Iii 2000; Au et al. 2006b). Males also produce sounds associated with aggression, which are generally characterized by frequencies between 50 hertz to 10 kilohertz with most energy below 3 kilohertz (Tyack 1983b;

Silber 1986b). Such sounds can be heard up to 9 kilometers (4.9 nautical miles) away (Tyack 1983b). Other social sounds from 50 hertz to 10 kilohertz (most energy below 3 kilohertz) are also produced in breeding areas (Tyack 1983b; Richardson et al. 1995f). While in northern feeding areas, both sexes vocalize in grunts (25 hertz to 1.9 kilohertz), pulses (25 to 89 hertz) and songs (ranging from 30 hertz to 8 kilohertz but dominant frequencies of 120 hertz to 4 kilohertz), which can be very loud (175 to 192 dB re: 1 μPa at 1 meter) (Payne 1985; Thompson et al. 1986b; Richardson et al. 1995f; Au et al. 2000; Erbe 2002b). However, humpback whales tend to be less vocal in northern feeding areas than in southern breeding areas (Richardson et al. 1995f). NMFS classified humpback whales in the low-frequency cetacean (i.e., baleen whale) functional hearing group. As a group, it is estimated that baleen whales can hear frequencies between 0.007 and 30 hertz (NOAA 2013a). Houser et al. (2001) produced a mathematical model of humpback whale hearing sensitivity based on the anatomy of the humpback whale ear. Based on the model, they concluded that humpback whales will be sensitive to sound in frequencies ranging from 0.7 to 10 kilohertz, with a maximum sensitivity between 2 to 6 kilohertz.

Humpback whales are known to produce three classes of vocalizations: (1) "songs" in the late fall, winter, and spring by solitary males; (2) social sounds made by calves (Zoidis et al. 2008) or within groups on the wintering (calving) grounds; and (3) social sounds made on the feeding grounds (Thomson and Richardson 1995b). The best-known types of sounds produced by humpback whales are songs, which are thought to be reproductive displays used on breeding grounds and sung only by adult males (Schevill et al. 1964; Helweg et al. 1992; Gabriele and Frankel. 2002; Clark and Clapham 2004; Smith et al. 2008). Singing is most common on breeding grounds during the winter and spring months, but is occasionally heard in other regions and seasons (McSweeney et al. 1989; Gabriele and Frankel. 2002; Clark and Clapham 2004). (Au et al. 2006a) noted that humpback whales off Hawaii tended to sing louder at night compared to the day. There is a geographical variation in humpback whale song, with different populations singing a basic form of a song that is unique to their own group. However, the song evolves over the course of a breeding season but remains nearly unchanged from the end of one season to the start of the next (Payne et al. 1983). The song is an elaborate series of patterned vocalizations that are hierarchical in nature, with a series of songs ('song sessions') sometimes lasting for hours (Payne and Mcvay 1971). Components of the song range from below 20 hertz up to 4 kilohertz, with source levels measured between 151 and 189 dB re: 1 μPa-m and high frequency harmonics extending beyond 24 kilohertz (Winn et al. 1970b; Au et al. 2006a). Social calls range from 20 hertz to 10 kilohertz, with dominant frequencies below 3 kilohertz (D'Vincent et al. 1985; Silber 1986b; Simao and Moreira 2005; Dunlop et al. 2008). Female vocalizations appear to be simple; Simao and Moreira (2005) noted little complexity.

"Feeding" calls, unlike song and social sounds are a highly stereotyped series of narrow-band trumpeting calls. These calls are 20 hertz to 2 kilohertz, less than one second in duration, and have source levels of 162 to 192 dB re: 1 μPa-m (D'Vincent et al. 1985; Thompson et al. 1986b). The fundamental frequency of feeding calls is approximately 500 Hertz (D'Vincent et al. 1985; Thompson et al. 1986b). The acoustics and dive profiles associated with humpback whale feeding behavior in the northwest Atlantic Ocean has been documented with digital acoustic recording tags (Stimpert et al. 2007). Underwater lunge behavior was associated with nocturnal feeding at depth and with multiple boats of broadband click trains that were acoustically different from toothed whale echolocation: (Stimpert et al. 2007) termed these sounds "mega-clicks" which showed relatively low received levels at the DTAGs (143 to 154 dB re: 1 μPa), with the majority of acoustic energy below 2 kilohertz.

In terms of functional hearing capability, humpback whales belong to low frequency cetaceans which have a hearing range of 7 hertz to 22 kilohertz (Southall et al. 2007b). Humpback whale audiograms using a mathematical model based on the internal structure of the ear estimate sensitivity is from 700 hertz to 10 kilohertz, with maximum relative sensitivity between 2 kilohertz and 6 kilohertz (Ketten and Mountain 2014). Research by Au et al. (2001) and Au et al. (2006a) off Hawaii indicated the presence of high frequency harmonics in vocalizations up to and beyond 24 kilohertz. While recognizing this was the upper limit of the recording equipment, it does not demonstrate that humpback whales can actually hear those harmonics, which may simply be correlated harmonics of the frequency fundamental in the humpback whale song. The ability of humpback whales to hear frequencies around 3 kilohertz may have been demonstrated in a playback study. Maybaum (1990b) reported that humpback whales showed a mild response to a handheld sonar marine mammal detection and location device with frequency of 3.3 kilohertz at 219 dB re: 1 μPa-m or frequency sweep of 3.1 to 3.6 kilohertz. In addition, the system had some low frequency components (below 1 kilohertz), which may have been an artifact of the acoustic equipment. This possible artifact may have affected the response of the whales to both the control and sonar playback conditions.

8.3.4 Status

Humpback whales were originally listed as endangered because of past commercial whaling, and the five DPSs that remain listed (Cape Verde Islands/Northwest Africa, Western North Pacific, Central America, Arabian Sea, and Mexico) have likely not yet recovered from this. According to historical whaling records from five whaling stations in British Columbia, 5,638 humpback whales were killed between 1908 and 1967 (Gregr et al. 2000). We have no way of knowing the degree to which a specific DPS of humpback whale was affected by historical whaling. However, it is likely that individuals from both the Mexico and Central America DPSs were taken, based on where the whalers were hunting off British Columbia (i.e., the purported feeding grounds for these population segments). Prior to commercial whaling, hundreds of thousands of humpback whales existed. Global abundance declined to the low thousands by 1968, the last year of substantial catches (IUCN 2012). Humpback whales may be killed under "aboriginal subsistence whaling" and "scientific permit whaling" provisions of the International Whaling Commission. Additional threats include ship strikes, fisheries interactions (including entanglement), energy development, and harassment from whaling watching noise, harmful algal blooms, disease, parasites, and climate change. Due to on-going threats, and the purported low population size, the Central America DPS still faces a risk of extinction. The Mexico DPS has a comparatively larger population than the Central America DPS, but still faces a risk of becoming endangered within the foreseeable future throughout all or a significant portion of its range.

8.3.5 Critical Habitat

Critical habitat has been designated for Central America and Mexico DPS humpback whales (86 FR 21082); see discussion in Section 7.2.5.1.

8.3.6 Recovery Goals

See the 1991 Final Recovery Plan for the humpback whale for the complete downlisting/delisting criteria for each of the four following recovery goals:

1. Maintain and enhance habitats used by humpback whales currently or historically.
2. Identify and reduce direct human-related injury and mortality.
3. Measure and monitor key population parameters.
4. Improve administration and coordination of recovery program for humpback whales.

8.4 Killer Whale—Southern Resident Distinct Population Segment

Killer whales are distributed worldwide, but populations are isolated by region and ecotype. Killer whales have been divided into distinct population segments on the basis of differences in genetics, ecology, morphology and behavior. The Southern Resident DPS of killer whale can be found along the Pacific Coast of the United States and Canada, and in the Salish Sea, Strait of Juan de Fuca, and Puget Sound (Figure 11).

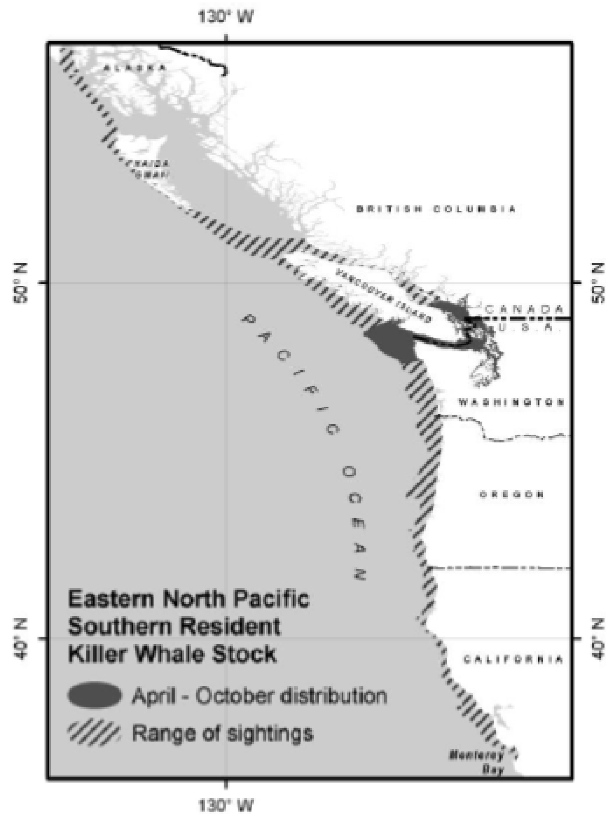

Figure 11. Map identifying the distribution and range of sightings of the endangered Southern Resident distinct population segment of killer whale. Approximate April through October distribution of the Southern Resident distinct population segment of killer whale (shaded area) and range of sightings (diagonal lines) (Carretta 2019b).

Killer whales are odontocetes and the largest delphinid species with black coloration on their dorsal side and white undersides and patches near the eyes. They also have a highly variable gray or white saddle behind the dorsal fin. The Southern Resident killer whales was listed as endangered under the ESA on November 18, 2005.

We used information available in the final rule, the Recovery Plan (NMFS 2008d), the 2016 Status Review (NMFS 2016h) and the recent stock assessment reports (Carretta 2019b; Carretta 2019a) to summarize the life history, population dynamics and status of this species, as follows.

8.4.1 Life History

Southern Resident DPS of killer whales are geographically, matrilineally, and behaviorally distinct from other killer whale populations. The Southern Resident DPS includes three large, stable pods (J, K, and L), which occasionally interact (Parsons et al. 2009a). Most mating occurs outside natal pods, during temporary associations of pods, or as a result of the temporary dispersal of males (Pilot et al. 2010). Males become sexually mature at 10 to 17 years of age. Females reach maturity at 12 to 16 years of age and produce an average of 5.4 surviving calves during a reproductive life span of approximately 25 years. Mating is believed to mostly occur in

May through October, and calves are born in all months, suggesting conception can happen year-round. Mothers and offspring maintain highly stable, life-long social bonds, and this natal relationship is the basis for a matrilineal social structure. Post-reproductive grandmothers (>45 years old) provide survival benefits to their grand offspring, possibly by using historical knowledge to lead the group in finding salmon, particularly during years of low to moderate salmon abundance (Nattrass et al. 2019).

Southern Resident killer whales communicate with one another while foraging, and share prey with others in the group (Ford and Ellis 2006; Wright et al. 2016). They prey upon fish, especially older and larger Chinook salmon (*Oncorhynchus tshawytscha*) in summer and fall, particularly those from the Fraser River (Hanson et al. 2010b). While on the outer coast, Southern Resident killer whales consume Chinook that originated in four river systems, mostly from the Columbia River (Hanson et al. 2021). Chinook remain an important prey item while the Southern Residents are in offshore coastal waters, where they also eat a greater diversity of fish species (NMFS 2019c). Southern Resident killer whales also eat chum (*O. keta*), Coho (*O. kitsutch*), and steelhead (*O. mykiss*), rockfish (*Sebastes spp.*), lingcod (*Ophiodon elongates*), Pacific halibut (*Hippoglossus stenolepis*), Pacific herring (*Clupea pallasi*), among others (Hanson et al. 2021).

A recent study of Southern Resident DPS of killer whale prey items at other times of the year (October through May) showed that Chinook remained an important prey item throughout the year in the Salish Sea and outer coast waters. Chinook comprised about 50 percent of Southern Resident DPS of killer whale diet in the fall, between 70 and 80 percent in the mid-winter and early spring, and nearly 100 percent in spring. Chum is consumed mainly in fall and winter (October through January; (Hanson et al. 2021).

8.4.2 Population Dynamics

The most recent abundance estimate for the Southern Resident DPS is 75 whales in 2019, and was previously 75 whales in 2018 (Carretta 2019a). The population is at 75 whales as of February 21, 2021[1]. This represents a decline from the recent past, when in 2012, there were 85 whales. Population abundance has fluctuated over time with a maximum of 99 whales in 1995 (Carretta 2019a; Carretta 2019b), with an increase between 1974 and the mid-90s, from 76 to 93 individuals. As compared to stable or growing populations, the DPS reflects lower fecundity and has demonstrated little to no growth in recent decades (NMFS 2016h). For the period between 1974 and the mid-1990s, when the population increased from 76 to 93 animals, the population growth rate was 1.8 percent (Ford et al. 1994). More recent data indicate the population is now in decline (Carretta 2019a; Carretta 2019b). Prior to 2019, there had been no Southern Resident killer whales born since 2015[2]. In 2019, two whales were born, one in L pod, and one in J pod. In 2020, two calves were born in J pod, and one calf born in 2021 to L pod.[2] Four whales died or were presumed dead following the 2018 census, as of July 1, 2019 (NMFS 2019c), L-41, a 42

[1] http://www.orcanetwork.org/Main/index.php?categories_file=Births%20and%20Deaths; accessed 3/2/2021.

year old male, died in January 2020.[2] Nutritional stress in the forms of lack of prey, toxin loads, and vessel disturbance is thought to be a possible contributing factor to low offspring production for Southern Residents. Analysis of fecal hormones has indicated several miscarriages in recent years, particularly in late pregnancy (Wasser et al. 2017). The number of effective breeders in the population is about 26 (Ford et al. 2018a).

After thorough genetic study, the Biological Review Team concluded that Southern Resident DPS of killer whales were discrete from other killer whale groups (NMFS 2008). Despite the fact that their ranges overlap, Southern Resident DPS of killer whales do not intermix with Northern Resident killer whales. Low genetic diversity within a population is believed to be in part due to the matrilineal social structure (NMFS 2008d). Inbreeding is a concern for the Southern Residents; four cases of inbreeding have been recorded, two between parent and offspring, one between paternal half-siblings, and one between an uncle and a half-niece; the fitness consequences of inbreeding in this population are unknown (Ford et al. 2018a).

Southern Resident DPS of killer whales occur for part of the year in the inland waterways of Puget Sound, Strait of Juan de Fuca, and Southern Georgia Strait mostly during the spring, summer and fall. Their movement patterns appear related to the seasonal availability of prey, especially Chinook salmon. They also move to coastal waters primarily off Washington and British Columbia, and have been sighted as far as central California and southeast Alaska (Figure 11) (NMFS 2019c). There is evidence to show that the different pods spend time in different locations while in coastal waters; see section 10.2.1.1 for more details. Results from satellite tagging, acoustic recording data, and opportunistic sightings indicate that Southern Resident killer whales spend the majority of their time on the continental shelf, within 34 kilometers of shore (NMFS 2019c).

8.4.3 Vocalization and Hearing

Killer whales have advanced vocal communication and also use vocalizations to aid in navigation and foraging (NMFS 2008d). Their vocalizations typically have both a low frequency component (250 hertz to 1.5 kilohertz) and a high frequency component (5 to 12 kilohertz) (NMFS 2008d). Killer whale vocalizations consist of three main types, echolocation clicks, which are primarily used for navigation and foraging, and tonal whistles and pulse calls, which are thought to be used for communication (NMFS 2008d). The interval of clicks during foraging varies with depth, with slower repetition click trains mostly occurring at shallow depths (> 20 meters), and faster clicks occurring at deeper depths. These results indicate that Southern Residents spend the majority of the their foraging time (74 percent) near the surface searching for prey, and then diving to intercept prey (Holt et al. 2019). Resident killer whales off British Columbia produce whistles for long-range communication like during foraging and slow traveling, and social interactions with the clan and between different groups (Thomsen et al. 2002; Riesch et al. 2006). Individual Southern Resident killer whale pods have distinct call

[2] http://www.orcanetwork.org/Main/index.php?categories_file=Births%20and%20Deaths (Accessed 3/4/2021).

repertoires, with each pod being recognizable by its acoustic dialect (NMFS 2008d). Killer whale hearing is one of the most sensitive of any odontocete, with a hearing range of 600 hertz to 114 kilohertz, with the most sensitive range being between 5 and 81 kilohertz (Branstetter et al. 2017).

8.4.4 Status

The Southern Resident DPS of killer whale was listed as endangered in 2005 in response to the population decline from 1996 through 2001, small population size, and reproductive limitations (i.e., few reproductive males and delayed calving). Current threats to its survival and recovery include contaminants, vessel traffic, and reduction in prey availability. Chinook salmon populations have declined due to degradation of habitat, hydrology issues, harvest, and hatchery introgression; such reductions may require an increase in foraging effort. In addition, these prey contain environmental pollutants. These contaminants become concentrated at higher trophic levels and may lead to immune suppression or reproductive impairment. The inland waters of Washington and British Columbia support a large whale watch industry, commercial shipping, and recreational boating; these activities generate underwater noise, which may mask whales' communication or interrupt foraging. The DPS's resilience to future perturbation is reduced as a result of its small population size. The recent decline, unstable population status, and population structure (e.g., few reproductive age males and non-calving adult females) continue to be causes for concern. The relatively low number of individuals in this population makes it difficult to resist or recover from natural spikes in mortality, including disease and fluctuations in prey availability.

8.4.5 Critical Habitat

Southern Resident killer whale proposed and designated critical habitat was described in Section 7.2.5.1.

8.4.6 Recovery Goals

See the 2008 Recovery Plan for the Southern Resident DPS of killer whale for complete downlisting/delisting criteria for each of the following recovery goals:

- Prey Availability: Support salmon restoration efforts in the region including habitat, harvest and hatchery management considerations and continued use of existing NMFS authorities under the ESA and Magnuson-Stevens Fishery Conservation and Management Act to ensure an adequate prey base
- Pollution/Contamination: Clean up existing contaminated sites, minimize continuing inputs of contaminants harmful to killer whales, and monitor emerging contaminants.
- Vessel Effects: Continue with evaluation and improvement of guidelines for vessel activity near Southern Resident DPS of killer whales and evaluate the need for regulations or protected areas.

- Oil Spills: Prevent oil spills and improve response preparation to minimize effects on Southern Resident DPS and their habitat in the event of a spill.
- Acoustic Effects: Continue agency coordination and use of existing ESA and MMPA mechanisms to minimize potential impacts from anthropogenic sound.
- Education and Outreach: Enhance public awareness, educate the public on actions they can participate in to conserve killer whales and improve reporting of Southern Resident DPS killer whale sightings and strandings.
- Response to Sick, Stranded, Injured Killer Whales: Improve responses to live and dead killer whales to implement rescues, conduct health assessments, and determine causes of death to learn more about threats and guide overall conservation efforts.
- Transboundary and Interagency Coordination: Coordinate monitoring, research, enforcement, and complementary recovery planning with Canadian agencies, and Federal and State partners.
- Research and Monitoring: Conduct research to facilitate and enhance conservation efforts. Continue the annual census to monitor trends in the population, identify individual animals, and track demographic parameters.

8.5 Sei Whale

The sei whale is a widely distributed baleen whale found in all major oceans. Sei whales are distinguishable from other whales by a long, sleek body that is dark bluish-gray to black in color and pale underneath, and a single ridge located on their rostrum. The sei whale was originally listed as endangered on December 2, 1970.

Information available from the recovery plan (NMFS 2011f), recent stock assessment report (Carretta 2019b), and status review (NMFS 2012b) were used to summarize the life history, population dynamics, and status of the species as follows.

8.5.1 Life History

Sei whales can live, on average, between 50 and 70 years. They have a gestation period of ten to 12 months, and calves nurse for six to nine months. Sexual maturity is reached between 6 and 12 years of age with an average calving interval of two to three years. Sei whales mostly inhabit continental shelf and slope waters far from the coastline. They winter at low latitudes, where they calve and nurse, and summer at high latitudes, where they feed on a range of prey types, including: plankton (copepods and krill) small schooling fishes, and cephalopods.

8.5.2 Population Dynamics

Two subspecies of sei whale are recognized, *B. b. borealis* in the Northern Hemisphere and *B. b. schlegellii* in the Southern Hemisphere. Models indicate that total abundance declined from 42,000 to 8,600 individuals between 1963 and 1974 in the North Pacific Ocean. More recently, the North Pacific Ocean population was estimated to be 29,632 (95 percent confidence intervals

18,576 to 47,267) between 2010 and 2012 (IWC 2016; Thomas et al. 2016). The best abundance estimate for sei whales for the waters of the U.S. West Coast is 519 (CV=0.40) (Carretta 2019b).

Population growth rates for sei whales are not available at this time as there are little to no systematic survey efforts to study sei whales.

Based on genetic analyses, there appears to be some differentiation between sei whale populations in different ocean basins. An early study of allozyme variation at 45 loci found some genetic differences between Southern Ocean and the North Pacific sei whales (Wada and Numachi 1991). However, more recent analyses of mtDNA control region variation show no significant differentiation between Southern Ocean and the North Pacific sei whales, though both appear to be genetically distinct from sei whales in the North Atlantic (Baker and Clapham 2004; Huijser et al. 2018). Within ocean basin, there appears to be intermediate to high genetic diversity and little genetic differentiation despite there being different managed stocks (Danielsdottir et al. 1991; Kanda et al. 2006; Kanda et al. 2011; Kanda et al. 2013; Kanda et al. 2015; Huijser et al. 2018).

Sei whales are distributed worldwide, occurring in the North Atlantic Ocean, North Pacific Ocean, and Southern Hemisphere. Very little is known about the distribution of sei whales in the northeast Pacific. Generally, the species occupies pelagic habitats, and is very rarely seen inshore; over 3,700 sei whales were killed by whales offshore of the west coast of Vancouver Island. In the recent past, two sei whales have been sighted in Canadian Pacific waters, one in 2004 off southeastern Haida Gwaii, and the other in 2008 near Learmonth Bank in Dixon Entrance (Nichol 2011).

8.5.3 Vocalization and Hearing

Data on sei whale vocal behavior is limited, but includes records off the Antarctic Peninsula of broadband sounds in the 100 to 600 hertz range with 1.5 second duration and tonal and upsweep calls in the 200 to 600 hertz range of one to three second durations (McDonald et al. 2005). Vocalizations from the North Atlantic Ocean consisted of paired sequences (0.5 to 0.8 seconds, separated by 0.4 to 1.0 seconds) of 10 to 20 short (4 milliseconds) frequency modulated sweeps between 1.5 to 3.5 kilohertz (Thomson and Richardson 1995c). Source levels of 189 ±5.8 dB re: 1 μPa at 1 meter have been established for sei whales in the northeastern Pacific Ocean (Weirathmueller 2013).

Direct studies of sei whale hearing have not been conducted, but it is assumed that they can hear the same frequencies that they produce (low) and are likely most sensitive to this frequency range (Richardson et al. 1995c; Ketten 1997). This suggests sei whales, like other baleen whales, are more likely to have their best hearing capacities at low frequencies, including frequencies lower than those of normal human hearing, rather than mid- to high-frequencies (Ketten 1997). In terms of functional hearing capability, sei whales belong to the low-frequency group, which have a hearing range of 7 hertz to 35 kilohertz (NOAA 2018).

8.5.4 Status

The sei whale is endangered as a result of past commercial whaling, reduced to about 20 percent of their pre-whaling abundance in the North Pacific Ocean (Carretta 2019b). According to historical whaling records from five whaling stations in British Columbia, 4,002 sei whales were killed between 1908 and 1967 (Gregr et al. 2000). Current threats include ship strikes, fisheries interactions (including entanglement), climate change (habitat loss and reduced prey availability), and anthropogenic sound. Given the species' overall abundance, they may be somewhat resilient to current threats. However, trends are largely unknown, especially for individual stocks, many of which have relatively low abundance estimates.

8.5.5 Critical Habitat

No critical habitat has been designated for the sei whale.

8.5.6 Recovery Goals

See the 2011 Final Recovery Plan for the sei whale for complete downlisting/delisting criteria for both of the following recovery goals:

1. Achieve sufficient and viable populations in all ocean basins.
2. Ensure significant threats are addressed.

8.6 Sperm Whale

The sperm whale is a widely distributed species found in all major oceans. Sperm whales are the largest toothed whale and distinguishable from other whales by its extremely large heard, which takes up to 25 to 35 percent of its total body length and a single blowhole asymmetrically situated on the left side of the head near the tip. The sperm whale was originally listed as endangered on December 2, 1970.

Information available from the recovery plan (NMFS 2010a), recent stock assessment reports (Carretta 2019b; Carretta 2019a), and status review (NMFS 2015g) were used to summarize the life history, population dynamics, and status of the species as follows.

8.6.1 Life History

The average lifespan of sperm whales is estimated to be at least 50 years (Whitehead 2009). They have a gestation period of one to one and a half years, and calves nurse for approximately two years. Sexual maturity for sperm whales in the North Pacific is reached between 7 and 13 years of age for females with an average calving interval for four to six years. Male sperm whales reach full sexual maturity between ages 18 and 21, after which they undergo a second growth spurt, reaching full physical maturity at around age 40 (Mizroch and Rice 2013). Data from historical whaling station records from 1908 to 1967 indicate that sperm whales mated in April through June, and calved in July to August in the offshore waters of British Columbia (Gregr et al. 2000). Sperm whales mostly occur far offshore, inhabiting areas with a water depth of 600 meters (1,968 feet) or more, and are uncommon in waters less than 300 meters (984 feet) deep. However, if there are shelf breaks or submarine canyons close to land, sperm whales can occur there. They winter at low latitudes, where they calve and nurse, and summer at high latitudes, where they feed primarily on squid; other prey includes octopus and demersal fish (including teleosts and elasmobranchs). An analysis of commercial whaling records from the Coal Harbor whaling station in northern Vancouver from 1963 to 1967 looked at sperm whale stomach contents. The samples came late spring through summer (April through September). North Pacific giant squid (*Moroteuhis robusta*) was the most abundant prey item for both males and females, but the secondary prey item differed between sexes. After giant squid, males consumed rockfish (*Sebastes spp*.), while females ate ragfish (*Icosteus spp*.) and other fish (Flinn et al. 2002).

8.6.2 Population Dynamics

The sperm whale is the most abundant of the large whale species, with a global population of between 300,000 and 450,000 individuals (Whitehead 2009). The higher estimates may be approaching population sizes prior to commercial whaling. In the northeast Pacific Ocean, the abundance of sperm whales was estimated to be between 26,300 and 32,100 in 1997 (NMFS 2015b). There is insufficient data to evaluate trends in abundance and growth rates of sperm whales at this time.

Ocean-wide genetic studies indicate sperm whales have low genetic diversity, suggesting a recent bottleneck, but strong differentiation between matrilineally related groups (Lyrholm and Gyllensten 1998). Consistent with this, two studies of sperm whales in the Pacific Ocean indicate low genetic diversity (Mesnick et al. 2011; Rendell et al. 2012). As none of the stocks for which data are available have high levels of genetic diversity, the species may be at some risk to inbreeding and 'Allee' effects, although the extent to which is currently unknown.

Sperm whales have a global distribution and can be found in relatively deep waters in all ocean basins. While both males and females can be found in latitudes less than 40°, only adult males venture into the higher latitudes near the poles. Sperm whale distribute widely throughout the North Pacific Ocean, with movements over 5,000 kilometers, likely driven by changes in prey abundance. Males appear to range more broadly than females (Mizroch and Rice 2013).

8.6.3 Vocalization and Hearing

Sound production and reception by sperm whales are better understood than in most cetaceans. Recordings of sperm whale vocalizations reveal that they produce a variety of sounds, such as clicks, gunshots, chirps, creaks, short trumpets, pips, squeals, and clangs (Goold 1999). Sperm whales typically produce short duration repetitive broadband clicks with frequencies below 100 hertz to greater than 30 kilohertz (Watkins 1977) and dominant frequencies between 1 to 6 kilohertz and 10 to 16 kilohertz. Another class of sound, "squeals," are produced with frequencies of 100 hertz to 20 kilohertz (e.g., Weir et al. 2007). The source levels of clicks can reach 236 dB re: 1 μPa at 1 meter, although lower source level energy has been suggested at around 171 dB re: 1 μPa at 1 meter (Weilgart and Whitehead 1993; Goold and Jones 1995;

Weilgart and Whitehead 1997a; Mohl et al. 2003). Most of the energy in sperm whale clicks is concentrated at around 2 to 4 kilohertz and 10 to 16 kilohertz (Weilgart and Whitehead 1993; Goold and Jones 1995). The clicks of neonate sperm whales are very different from typical clicks of adults in that they are of low directionality, long duration, and low frequency (between 300 hertz and 1.7 kilohertz) with estimated source levels between 140 to 162 dB re: 1 μPa at 1 meter (Madsen et al. 2003). The highly asymmetric head anatomy of sperm whales is likely an adaptation to produce the unique clicks recorded from these animals (Norris and Harvey 1972).

Long, repeated clicks are associated with feeding and echolocation (Whitehead and Weilgart 1991; Weilgart and Whitehead 1993; Goold and Jones 1995; Weilgart and Whitehead 1997a; Miller et al. 2004). Creaks (rapid sets of clicks) are heard most frequently when sperm whales are foraging and engaged in the deepest portion of their dives, with inter-click intervals and source levels being altered during these behaviors (Miller et al. 2004; Laplanche et al. 2005). Clicks are also used during social behavior and intragroup interactions (Weilgart and Whitehead 1993). When sperm whales are socializing, they tend to repeat series of group-distinctive clicks (codas), which follow a precise rhythm and may last for hours (Watkins and Schevill 1977). Codas are shared between individuals in a social unit and are considered to be primarily for intragroup communication (Weilgart and Whitehead 1997a; Rendell and Whitehead 2004). Research in the South Pacific Ocean suggests that in breeding areas the majority of codas are produced by mature females (Marcoux et al. 2006). Coda repertoires have also been found to vary geographically and are categorized as dialects (Weilgart and Whitehead 1997a; Pavan et al. 2000). For example, significant differences in coda repertoire have been observed between sperm whales in the Caribbean Sea and those in the Pacific Ocean (Weilgart and Whitehead 1997a). Three coda types used by male sperm whales have recently been described from data collected over multiple years: these codas are associated with dive cycles, socializing, and alarm (Frantzis and Alexiadou 2008).

Our understanding of sperm whale hearing stems largely from the sounds they produce. The only direct measurement of hearing was from a young stranded individual from which auditory evoked potentials were recorded (Carder and Ridgway 1990). From this whale, responses support a hearing range of 2.5 to 60 kilohertz and highest sensitivity to frequencies between 5 to 20 kilohertz. Other hearing information consists of indirect data. For example, the anatomy of the sperm whale's inner and middle ear indicates an ability to best hear high-frequency to ultrasonic hearing (Ketten 1992). The sperm whale may also possess better low-frequency hearing than other odontocetes, although not as low as many baleen whales (Ketten 1992). Reactions to anthropogenic sounds can provide indirect evidence of hearing capability, and several studies have made note of changes seen in sperm whale behavior in conjunction with these sounds. For example, sperm whales have been observed to frequently stop echolocating in the presence of underwater pulses made by echosounders and submarine sonar (Watkins and Schevill 1975b; Watkins et al. 1985). In the Caribbean Sea, Watkins et al. (1985) observed that sperm whales exposed to 3.25 to 8.4 kilohertz pulses (presumed to be from submarine sonar) interrupted their activities and left the area. Similar reactions were observed from artificial sound generated by banging on a boat hull (Watkins et al. 1985). André et al. (1997) reported that foraging whales exposed to a 10 kilohertz pulsed signal did not ultimately exhibit any general avoidance reactions: when resting at the surface in a compact group, sperm whales initially reacted strongly, and then ignored the signal completely. Thode et al. (2007) observed that the acoustic signal from the cavitation of a fishing vessel's propeller (110 dB re: 1 μPa^2-s between 250 hertz and 1 kilohertz) interrupted sperm whale acoustic activity and resulted in the animals converging on the vessel. Sperm whales have also been observed to stop vocalizing for brief periods when codas are being produced by other individuals, perhaps because they can hear better when not vocalizing themselves (Goold and Jones 1995). Because they spend large amounts of time at depth and use low frequency sound, sperm whales are likely to be susceptible to low frequency sound in the ocean (Croll et al. 1999). Nonetheless, sperm whales are considered to be part of the mid-frequency marine mammal hearing group, with a hearing range between 150 hertz and 160 kilohertz (NOAA 2018).

8.6.4 Status

The sperm whale is endangered as a result of past commercial whaling. According to historical whaling records from five whaling stations in British Columbia, 6,158 sperm whales were killed between 1908 and 1967 (Gregr et al. 2000). Although the aggregate abundance worldwide is probably at least several hundred thousand individuals, the extent of depletion and degree of recovery of populations are uncertain. Commercial whaling is no longer allowed, however, illegal hunting may occur at biologically unsustainable levels. Continued threats to sperm whale populations include ship strikes, entanglement in fishing gear, competition for resources due to overfishing, population, loss of prey and habitat due to climate change, and noise. The species' large population size shows that it is somewhat resilient to current threats.

8.6.5 Critical Habitat

No critical habitat has been designated for the sperm whale.

8.6.6 Recovery Goals

See the 2010 Final Recovery Plan for the sperm whale for complete downlisting/delisting criteria for both of the following recovery goals:

1. Achieve sufficient and viable populations in all ocean basins.
2. Ensure significant threats are addressed.

8.7 Guadalupe Fur Seal

Guadalupe fur seals were once found throughout Baja California, Mexico and along the California coast. Currently, the species breeds mainly on Guadalupe Island, Mexico, off the coast of Baja California. A smaller breeding colony, discovered in 1997, appears to have been established at Isla Benito del Este in the San Benito Archipelago, Baja California, Mexico (Belcher and T.E. Lee 2002).

Guadalupe fur seals are medium sized, sexually dimorphic otariids (Belcher and T.E. Lee 2002; Reeves et al. 2002). Distinguishing characteristics of the Guadalupe fur seal include the digits on their hind flippers (all of similar length), large, long foreflippers, and unique vocalizations (Reeves et al. 2002). Guadalupe fur seals are dark brown to black, with the adult males having tan or yellow hairs at the back of their mane. Guadalupe fur seals were listed as threatened under the ESA on December 16, 1985 (50 FR 51252).

8.7.1 Life History

Guadalupe fur seals prefer rocky habitats and can be found in natural recesses and caves (Fleischer 1978), using sheltered beaches and rocky platforms for breeding (Arias-del-Razo et al. 2016). Breeding occurs in June through August. Adult males return to the colonies in early June. Female Guadalupe fur seals arrive on beaches in June, with births occurring between mid-June to July (Pierson 1978); the pupping season is generally over by late July (Fleischer 1978). Breeding adult males are polygamous, and may mate with up to 12 females during a single breeding season. Females stay with pups for seven to eight days after parturition, and then alternate between foraging trips at sea and lactation on shore; nursing lasts about eight months (Figureroa-Carranza 1994). Guadalupe fur seals feed mainly on squid species (Esperon-Rodriguez and Gallo-Reynoso 2013); the Gulf of Ulloa on the Pacific side of the Baja California peninsula is an important feeding area (Aurioles-Gamboa and Szteren 2019). Based on a stable isotope analysis of male Guadalupe fur seal carcasses, there appears to be some niche segregation between coastal and oceanic males, possibly based on individual age and size (Aurioles-Gamboa and Szteren 2019). Foraging trips can last between four to twenty-four days (average of fourteen days). Tracking data show that adult females spend seventy-five percent of their time sea, and twenty-five percent at rest (Gallo-Reynoso et al. 1995).

8.7.2 Population Dynamics

It is difficult to obtain an accurate abundance estimate of Guadalupe fur seals due in part to their tendency to stay in caves and remain at sea for extended lengths of time, making them unavailable for counting. At the time of listing in 1985, the population was estimated at 1,600 individuals, compared to approximately 30,000 before hunting occurred in the 18th and 19th centuries. A population was "rediscovered" in 1928 with the capture of two males on Guadalupe Island; from 1949 on, researchers reported sighting Guadalupe fur seals at Isla Cedros (near the San Benito Archipelago), and Guadalupe Island (Bartholomew Jr. 1950; Peterson et al. 1968). In 1994, the population at Guadalupe Island was estimated at 7,408 individuals (Gallo-Reynoso 1994). There have been other, more recent population abundance estimates for Guadalupe Island, with a considerable amount of variation between them: 20,000 in 2010 (García-Capitanachi et al. 2017), and between 34,000 and 44,000 in 2013 (García-Aguilar et al. 2018). Guadalupe fur seals are also found on San Benito Island, likely immigrants from Guadalupe Island, as there are relatively few pups born on San Benito Island (Aurioles-Gamboa et al. 2010). There were an estimated 2,504 seals on San Benito Island in 2010 (García-Capitanachi et al. 2017). Based on information presented by (García-Aguilar et al. 2018), and using a population size:pup count ratio of 3.5, the minimum population estimate is 31,019 (Carretta 2019a).

All Guadalupe fur seals represent a single population, with two known breeding colonies in Mexico, and a purported breeding colony in the United States. Gallo-Reynoso (1994) calculated that the population of Guadalupe fur seals in Mexico from thirty years of population and counts and concluded the population was increasing; with an average annual growth rate of 13.3 percent on Guadalupe Island. The 2000 NMFS stock assessment report for Guadalupe fur seals also indicated the breeding colonies in Mexico were increasing; and more recent evidence indicates that this trend is continuing (Aurioles-Gamboa et al. 2010; Esperon-Rodriguez and Gallo-Reynoso 2012). From 1984 to 2013 at Guadalupe Island, the Guadalupe fur seal population increased at an average annual growth rate of 5.9 percent (range 4.1 to 7.7 percent) (García-Aguilar et al. 2018). Other estimates of the Guadalupe fur seal population of the San Benito Archipelago (from 1997-2007) indicate that it is increasing as well at an annual rate of 21.6 percent (Esperon-Rodriguez and Gallo-Reynoso 2012), and that this population is at a phase of exponential increase (Aurioles-Gamboa et al. 2010). However, these estimates are considered too high, and likely result from immigration at Guadalupe Island (Carretta 2017; Carretta 2019a). Based on direct counts of animals from 1955 and 1993, the estimated annual population growth rate is 13.7 percent (Carretta 2019a).

The Guadalupe fur seal clearly experienced a precipitous decline due to commercial exploitation, and may have undergone a population bottleneck. Bernardi et al. (1998) compared the genetic divergence in the nuclear fingerprint of samples taken from 29 Guadalupe fur seals, and found an average similarity of 0.59 of the DNA profiles. This average is typical of outbreeding populations. When comparing the amount of unique character fragments found in Guadalupe fur seals to that of other pinnipeds that have experienced bottlenecks (e.g., Hawaiian monk seals), that amount is much higher (0.14 vs. 0.05) in Guadalupe fur seals than Hawaiian monk seals. By using mitochondrial DNA sequence analysis in comparing the genetic diversity of Guadalupe fur seals to northern elephant seals (which did experience a severe bottleneck), Guadalupe fur seals had more haplotypes and a higher number of variable sites. The authors hypothesized that the numbers of Guadalupe fur seals left after harvest may have been underestimated, and the population may not have actually experienced a bottleneck, or the bottleneck may have been of short duration and not severe enough to suppress genetic diversity. Although the relatively high levels of genetic variability are encouraging, it is important to note that commercial harvest still influenced the population. Later studies comparing mitochondrial DNA found in the bones of pre-exploitation Guadalupe fur seals against the extant population showed a loss of genotypes, with twenty-five genotypes in pre-harvest fur seals, and seven present today (Weber et al. 2004).

Guadalupe fur seals are known to travel great distances, with sightings occurring thousands of kilometers away from the main breeding colonies (Aurioles-Gamboa et al. 1999). Guadalupe fur seals are infrequently observed in U.S. waters. They can be found on California's Channel

Islands, with as many fifteen individuals being sighted since 1997 on San Miguel Island, including three females and reared pups.

8.7.3 Status

Commercial sealers in the 19th century decimated the Guadalupe fur seal population, taking as many 8,300 fur seals from San Benito Island (Townsend 1924). Numbers on the total number of fur seals harvested are difficult to ascertain because of the difficulty the hunters had in distinguishing species while hunting (Seagars 1984). These harvests were devastating for the Guadalupe fur seal population, so much so that in 1892, only seven individuals were observed on Guadalupe Island, the location of one of the larger known breeding colonies (Bartholomew Jr. 1950); two years later, a commercial sealer took all 15 remaining individuals that could be found (Townsend 1899).

The species was presumed extinct, until 1926, when a small herd was found on Guadalupe Island by commercial fishermen, who later returned and killed all the seals they could find. In 1928, the Mexican government declared Guadalupe Island as a pinniped sanctuary. In 1954, during a survey of the island, Hubbs (1956) discovered at least 14 individuals. The government of Mexico banned the hunting of Guadalupe fur seals in 1967. Although population surveys occurred on an irregular basis in subsequent years, evidence shows that the Guadalupe fur seal population has been increasing ever since (see Section 8.7.2).

How the Guadalupe fur seal population was able to persist despite intensive and repeated episodes of hunting is not precisely known, although several factors likely played a role. Hubbs (1956) postulated that since Guadalupe fur seals bred in caves, it made them difficult to find, and they were able to evade hunters. Furthermore, since the adult females spend up to 75 percent of their time at sea for two weeks or more at a time, enough females were away during hunting to survive these episodes.

Although a number of human activities may have contributed to the current status of this species, historic commercial hunting was likely the most devastating. Even with population surveys occurring on an irregular basis in subsequent years, these surveys provide evidence that the Guadalupe fur seal has been increasing after suffering such a significant decline. Although commercial hunting occurred in the past, and has since ceased, the effects of these types of exploitations persist today. Other human activities, such as entanglements from commercial fishing gear, are ongoing and continue to affect these species. While some incidental breeding takes place on the San Benito Islands and the Channel Islands, the Guadalupe Island breeding colony supports the population (García-Aguilar et al. 2018). The current abundance of the Guadalupe fur seal represents about one-fifth of the estimated historical population size, and although the population has continued to increase, the species has not expanded its breeding range, potentially affecting its recovery (García-Aguilar et al. 2018). Because, over the last fifty years, the population has been increasing since being severely depleted, we believe that the Guadalupe fur seal population is resilient to future perturbations.

8.7.4 Critical Habitat

No critical habitat has been designated for Guadalupe fur seals.

8.7.5 Recovery Goals

NMFS has not prepared a Recovery Plan for Guadalupe fur seals.

8.8 Leatherback Turtle

The leatherback sea turtle is unique among sea turtles for its large size, wide distribution (due to thermoregulatory systems and behavior), and lack of a hard, bony carapace. It ranges from tropical to subpolar latitudes, worldwide (Figure 12).

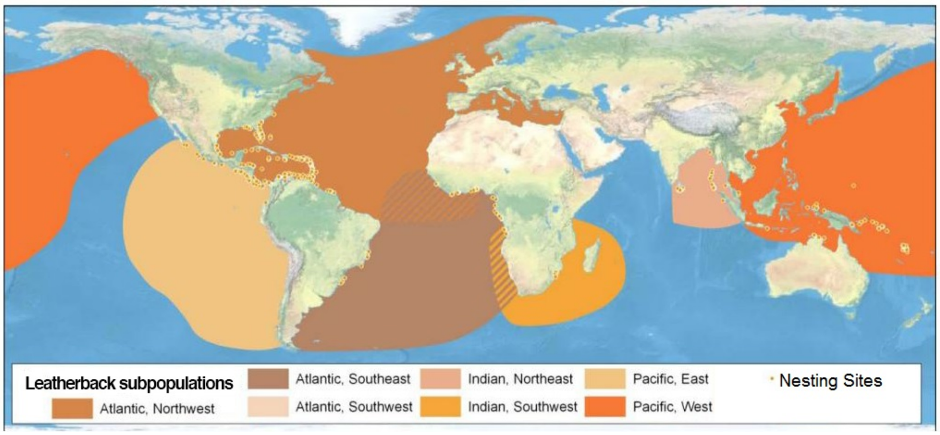

Figure 12. Map identifying the range of the endangered leatherback turtle. Adapted from (Wallace et al. 2013).

Leatherback turtles are the largest living turtle, reaching lengths of 2 meters (6.5 feet) long, and weighing up to 907.2 kilograms (2,000 pounds). Leatherback turtles have a distinct black leathery skin covering their carapace with pinkish white skin on their belly. The species was first listed under the Endangered Species Conservation Act (35 FR 8491) and listed as endangered under the ESA since 1973.

We used information available in the five year review (NMFS and USFWS 2013) and the critical habitat designation (77 FR 61573) to summarize the life history, population dynamics and status of the species, as follows.

8.8.1 Life History

Age at maturity has been difficult to ascertain, with estimates ranging from five to 29 years (Spotila et al. 1996; Avens et al. 2009). Females lay up to seven clutches per season, with more than sixty-five eggs per clutch and eggs weighing greater than 80 grams (0.17 pounds) (Reina et al. 2002; Wallace et al. 2007). The number of leatherback turtle hatchlings that make it out of the nest on to the beach (i.e., emergent success) is approximately 50 percent worldwide (Eckert et al. 2012). Females nest every one to seven years. Natal homing, at least within an ocean basin, results in reproductive isolation between five broad geographic regions: eastern and western

Pacific, eastern and western Atlantic, and Indian Ocean. Leatherback turtles migrate long, transoceanic distances between their tropical nesting beaches and the highly productive temperate waters where they forage, primarily on jellyfish and tunicates. These gelatinous prey are relatively nutrient-poor, such that leatherback turtles must consume large quantities to support their body weight. Leatherback turtles weigh about 33 percent more on their foraging grounds than at nesting, indicating that they probably catabolize fat reserves to fuel migration and subsequent reproduction (James et al. 2005; Wallace et al. 2006). Sea turtles must meet an energy threshold before returning to nesting beaches. Therefore, their remigration intervals (the time between nesting) are dependent upon foraging success and duration (Hays 2000; Price et al. 2004).

8.8.2 Population Dynamics

Leatherback turtles are globally distributed, with nesting beaches in the Atlantic, Indian, and Pacific Oceans. Detailed population structure is unknown, but is likely dependent upon nesting beach location. Based on estimates calculated from nest count data, there are between 34,000 and 94,000 adult leatherback turtles in the North Atlantic Ocean (TEWG 2007). In contrast, leatherback turtle populations in the Pacific Ocean are much lower. Overall, Pacific populations have declined from an estimated 81,000 individuals to less than 3,000 total adults and subadults (Spotila et al. 2000).

Population growth rates for leatherback turtles vary by ocean basin. Counts of leatherback turtles at nesting beaches in the western Pacific Ocean indicate that the subpopulation has been declining at a rate of almost six percent per year since 1984 (Tapilatu et al. 2013). Based on surveys over 28 years of feeding grounds off central California, leatherback abundance has declined at an annual rate of 5.6 percent, with no substantial changes noted in ocean conditions or prey availability (Benson et al. 2020).

Analyses of mitochondrial DNA from leatherback turtles indicates a low level of genetic diversity, pointing to possible difficulties in the future if current population declines continue (Dutton et al. 1999).

Leatherback turtles are distributed in oceans throughout the world (Figure 12). Leatherback turtles occur throughout marine waters, from nearshore habitats to oceanic environments (Shoop and Kenney 1992). During a seismic research survey in late summer 2009, about 250 kilometers offshore of Vancouver, a leatherback sea turtle was sighted (Holst 2017). Movements are largely dependent upon reproductive and feeding cycles and the oceanographic features that concentrate prey, such as frontal systems, eddy features, current boundaries, and coastal retention areas (Benson et al. 2011b).

8.8.3 Vocalization and Hearing

Sea turtles are low frequency hearing specialists, typically hearing frequencies from 30 hertz to 2 kilohertz, with a range of maximum sensitivity between 100 and 800 hertz (Ridgway et al. 1969; Lenhardt 1994; Bartol et al. 1999; Lenhardt 2002; Moein Bartol and Ketten 2006). Piniak (2012) measured hearing of leatherback turtle hatchlings in water an in air, and observed reactions to low frequency sounds, with responses to stimuli occurring between 50 hertz and 1.6 kilohertz in air between 50 hertz and 1.2 kilohertz in water (lowest sensitivity recorded was 93 dB re: 1 μPa at 300 hertz).

These hearing sensitivities are similar to those reported for two terrestrial species: pond and wood turtles. Pond turtles respond best to sounds between 200 and 700 hertz, with slow declines below 100 hertz and rapid declines above 700 hertz, and almost no sensitivity above 3 kilohertz (Wever and Vernon 1956). Wood turtles are sensitive up to about 500 hertz, followed by a rapid decline above 1 kilohertz and almost no responses beyond 3 to 4 kilohertz (Patterson 1966).

8.8.4 Status

The leatherback turtle is an endangered species whose once large nesting populations have experienced steep declines in recent decades. The primary threats to leatherback turtles include fisheries bycatch, harvest of nesting females, and egg harvesting. Because of these threats, once large rookeries are now functionally extinct, and there have been range-wide reductions in population abundance. Other threats include loss of nesting habitat due to development, tourism, and sand extraction. Lights on or adjacent to nesting beaches alter nesting adult behavior and are often fatal to emerging hatchlings as they are drawn to light sources and away from the sea. Plastic ingestion is common in leatherback turtles and can block gastrointestinal tracts leading to death. Climate change may alter sex ratios (as temperature determines hatchling sex), range (through expansion of foraging habitat), and habitat (through the loss of nesting beaches, because of sea-level rise). The species' resilience to additional perturbation is low.

8.8.5 Critical Habitat

Critical habitat within the action area has been designated for leatherback sea turtles on January 20, 2012 (50 C.F.R. §226). Leatherback turtle critical habitat was described in Section 7.5.3.

8.8.6 Recovery Goals

See the 1998 and 1991 Recovery Plans for the U.S. Pacific and U.S Caribbean, Gulf of Mexico and Atlantic leatherback turtles for complete down listing/delisting criteria for each of their respective recovery goals. The following items were the top five recovery actions identified in the Pacific Leatherback Five Year Action Plan:

1. Reduce fisheries interactions
2. Improve nesting beach protection and increase reproductive output
3. International cooperation
4. Monitoring and research
5. Public engagement

8.9 Green Sturgeon—Southern Distinct Population Segment

The North American green sturgeon, *Acipenser medirostris*, is an anadromous fish that occurs in the nearshore Eastern Pacific Ocean from Alaska to Mexico (Moyle 2002b). Green sturgeon are long-lived, late-maturing, iteroparous, anadromous species that spawn infrequently in natal streams, and spend substantial portions of their lives in marine waters. NMFS has identified two DPSs of green sturgeon; northern and southern (Israel et al. 2009). The northern DPS spawns primarily in the Klamath and Rogue Rivers, and occasionally in the Columbia River, while the southern DPS spawns exclusively in the Sacramento Basin (Schreier and Stevens 2020). The southern DPS green sturgeon includes individuals which spawn in the Sacramento, Feather, and Yuba rivers. In 2006, NMFS determined that the southern DPS green sturgeon warranted listing as a threatened species under the ESA (71 FR 17757).

Information available from the recovery plan (NMFS 2018b), status review (NMFS 2015f), and recent scientific publications were used to summarize the life history, population dynamics, and status of the species as follows.

8.9.1 Life History

Green sturgeon can live to be 70 years old. Green sturgeon reach sexual maturity at approximately 15 years of age (Van Eenennaam et al. 2006), and may spawn every one to four years throughout their long lives (Moser et al. 2016). Southern DPS green sturgeon spawn in cool (14 to 17 degrees Celsius), deep, turbulent areas with clean, hard substrates.

By far, the Sacramento River is the largest known spawning river for the southern DPS. Six discrete spawning sites have been identified in the upper Sacramento River between Gianella Bridge (river kilometer 320.6) and the Keswick dam (river kilometer 486) (Poytress et al. 2013). Spawning for the DPS occurs to a much lesser degree in the Yuba and Feather Rivers. Some minor spawning takes place in the Feather River, with between 21 to 28 sturgeon observed in 2011, and fertilized eggs on egg mats found (Seesholtz et al. 2015). Spawning pairs of green sturgeon were captured on video at the foot of a dam in the Yuba River in 2011 (Bergman et al. 2011).

In preparation for spawning, adult southern DPS green sturgeon enter San Francisco Bay between mid-February and early-May, then migrate rapidly (on the order of a few weeks) up the Sacramento River (Heublein et al. 2009). Spawning occurs from April through early July, with peaks of activity that depend on a variety of factors including water temperature and water flow rates (Poytress et al. 2009; Poytress et al. 2010). Post-spawn fish typically congregate and hold for several months in a few deep pools in the upper main stem Sacramento River near spawning sites and migrate back downstream when river flows increase in fall. They re-enter the ocean during the winter months (November through January) and begin their marine migration north along the coast (Erickson and Hightower 2007).

Green sturgeon larvae are different from all other sturgeon because of the absence of a distinct swim-up or post-hatching stage. Larvae grow fast; young fish grow to 74 millimeters 45 days after hatching (Deng 2000). Larvae and juveniles migrate downstream toward the Sacramento-San Joaquin Delta/Estuary, where they rear for one to four years before migrating out to the Pacific Ocean as subadults (Nakamoto et al. 1995). Acoustically tagged juveniles stayed mostly at or near the bottom while in the San Joaquin River Channel (Thomas et al. 2019). Once at sea, subadults and adults occupy coastal waters to a depth of 110 meters from Baja California, Mexico to the Bering Sea, Alaska (Erickson and Hightower 2007), and regularly aggregate in estuaries. Fish congregate in coastal bays and estuaries of Washington, Oregon, and California during summer and fall. In winter and spring, similar aggregations can be found from Vancouver Island to Hecate Strait, British Columbia, Canada (Lindley et al. 2008). Green sturgeon are found in Willapa Bay, Washington, from May through September, but acoustically-tagged individuals occur there over shorter time periods (34 days, ± 41 days SD) (Borin et al. 2017). Hansel et al. (2017) detected acoustically-tagged green sturgeon in the Columbia River Estuary from May to October.

Adults captured in the Sacramento-San Joaquin Delta are benthic feeders on invertebrates including shrimp, mollusks, amphipods, and even small fish (Houston 1988; Moyle et al. 1992a). Juveniles in the Sacramento River delta feed on opossum shrimp, *Neomysis mercedis*, and *Corophium* amphipods (Radtke 1966). Green sturgeon in Willapa Bay, Washington, eat burrowing shrimp (*Neotrypaea californiensis*) (Borin et al. 2017).

8.9.2 Population Dynamics

Mora et al. (2018) used dual-frequency identification sonar sampling in the Sacramento River for five years between 2010 and 2015 to estimate spawning run size and population size of the southern DPS green sturgeon. Southern DPS spawning run size varied across years, from a minimum of 336 to a maximum of 1,236 individuals. The total population size for the Sacramento River was estimated at 17,548 individuals (95 percent confidence interval [CI] = 12,614 to 22,482). The study also estimated the number of juveniles, sub-adults, and adults in the river. There are an estimated 4,387 juveniles (95 percent CI = 2,595 to 6,179), an estimated 11,055 subadults (95 percent CI = 6,540 to 15,571), and an estimated 2,106 adults (95 percent CI = 1,246 to 2,966) in the Sacramento River (Mora et al. 2018). Mora et al. (2015) did a similar study in the Rogue River and estimated the total abundance of green sturgeon to be 223 (95 percent CI = 150 to 424).

Attempts to evaluate the status of southern DPS green sturgeon have been met with limited success due to the lack of reliable long-term data. No estimate of intrinsic growth rate is available for southern DPS green sturgeon.

Green sturgeon stocks from the DPSs have been found to be genetically differentiated (Israel et al. 2004; Israel et al. 2009).

Green sturgeon from both the northern and southern DPSs range along the Pacific Coast (Moyle 2002b), with green sturgeon tagged and released in the Sacramento River later detected in Willapa Bay, Washington (Hansel et al. 2017). Green sturgeon have been observed in large concentrations in the summer and autumn within coastal bays and estuaries along the west coast of the US, including the Columbia River estuary, Willapa Bay, Grays Harbor, San Francisco Bay and Monterey Bay.

8.9.3 Hearing

Information available about the hearing abilities of green sturgeon come from studies of other species of sturgeon.

Meyer et al. (2003) investigated shortnose sturgeon (*Acipenser brevirostrum*) hearing abilities by using physiological methods to measure responses to pure tones. The authors presented shortnose sturgeon with pure tone stimuli from 50 to 1000 hertz with intensities ranging from of 120 to 160 dB re 1 µPa. Shortnose sturgeon were most sensitive to tones presented at 100 and 400 hertz although thresholds were not determined. Based on the limited data, sturgeon were able to detect sounds below 100 hertz to about 1,000 hertz and that sturgeon should be able to determine the direction of sounds (Popper 2005). Paillid sturgeon (*Scaphirhynchus albus*) and the shovelnose sturgeon (*S. platorynchus*) produce sounds like squeaks, chirps, knocks, and moans during the breeding season, and are thought to help individuals locate other sturgeon (Johnston and Phillips 2003).

Meyer (2010) recorded auditory evoked potentials to pure tone stimuli of varying frequency and intensity in lake sturgeon (*Acipenser fulvescens*) have best sensitivity from 50 to 400 hertz. Lovell (2005) also studied sound reception in and the hearing abilities of paddlefish (*Polyodon spathula*) and lake sturgeon in pressure dominated and particle motion dominated sound fields. They concluded that both species were responsive to sounds ranging in frequency from 100 to 500 hertz with lowest hearing thresholds from frequencies in bandwidths between 200 and 300 hertz and higher thresholds at 100 and 500 hertz. The results showed that both species were not sensitive to sound pressure, and would have a significantly higher hearing threshold in a pressure dominated sound field. Based on the above we assume that the hearing sensitivity of shortnose sturgeon is best between 100 to 500 hertz with sensitivity falling up to 1,000 hertz.

BOEM (2012) categorized sturgeon in general as fishes that detect sounds from below 50 hertz to perhaps 800 to 1,000 hertz (though several probably only detect sounds to 600 to 800 hertz). Green sturgeon have a swim bladder but no known structures in the auditory system that would enhance hearing, and sensitivity (lowest sound detectable at any frequency) is not very great. Sounds would have to be more intense to be detected compared to fishes with swim bladders that enhance hearing. Sturgeon can detect both particle motion and pressure.

8.9.4 Status

Attempts to evaluate the status of southern DPS green sturgeon have been met with limited success due to the lack of reliable long-term data. However, based on available scientific data (Adams et al. 2007) and ongoing conservation efforts, NMFS concluded in the final rule designating this species that southern DPS green sturgeon were likely to become endangered in the foreseeable future throughout all of its range. The final rule listing southern DPS green sturgeon indicates that the principle factor for the decline in the DPS is the reduction of spawning to a limited area in the Sacramento River caused primarily by impoundments. The species also faces threats from changes in water temperature, availability, and flow, and commercial and recreational bycatch (71 FR 17757). Climate change has the potential to impact southern DPS green sturgeon in the future, but it is unclear how changing oceanic, nearshore and river conditions will affect the southern DPS overall (NMFS 2015f).

8.9.5 Critical Habitat

Critical habitat was designated for southern DPS green sturgeon on October 9, 2009, and includes marine, coastal bay, estuarine, and freshwater areas (74 FR 52300). Southern DPS green sturgeon critical habitat was described in Section 7.2.5.6.

8.9.6 Recovery Goals

The final recovery plan for southern DPS green sturgeon indicates that the recovery potential for southern DPS green sturgeon is considered moderate to high (NMFS 2018b); however, certain life history characteristics (e.g., long-lived, delayed maturity) indicate recovery could take many decades, even under the best circumstances. According to the recovery plan key recovery needs and implementation measures include additional spawning and egg/larval habitat, as well as additional research and monitoring (NMFS 2018b).

8.10 Eulachon—Southern Distinct Population Segment

The eulachon is a small, cold-water species of anadromous fish, occupying the eastern Pacific Ocean in nearshore waters to depths of about 1,000 feet (300 meters) from California to the Bering Sea. Eulachon will return to their natal river spawn. Southern DPS eulachon are those that spawn in rivers south of the Nass River in British Columbia to the Mad River in California (Figure 15) (NMFS 2016e).

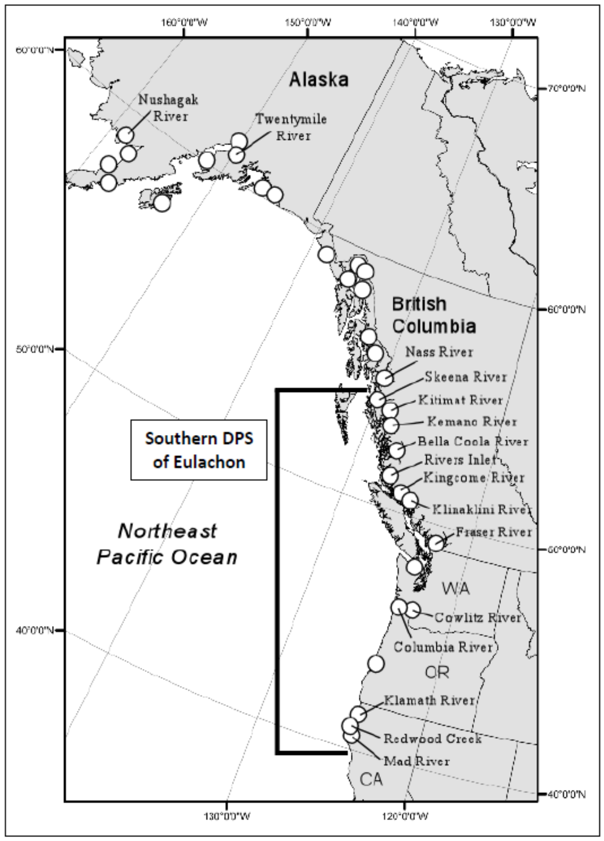

Figure 13. Map identifying the range of the eulachon Southern distinct population segment (NMFS 2016e).

Eulachon are a small (8.5 inches [21.5 centimeters]) anadromous fish, with brown or blue backs, silver on their sides, and white underneath. The Southern DPS was first listed as threatened by NMFS on March 18, 2010 (75 FR 13012).

We used information available in the status review (Gustafson et al. 2010), the updated status review (Gustafson 2016a), the 5-year review (NMFS 2016e), and recent scientific publications to summarize the life history, population dynamics and status of the species, as follows.

8.10.1 Life History

Although primarily marine, eulachon return to freshwater to spawn. For the Southern DPS eulachon, most spawning occurs in the Columbia River and its tributaries. Spawning usually occurs between ages two and five. Spawning is strongly influenced by water temperatures, and the timing of migration typically occurs between December and June, when water temperatures are between 0°C and 10°C (Gustafson 2016a). In the Columbia River and further south, spawning occurs from late January to March (Hay and McCarter 2000). Further north, the peak of eulachon runs in Washington State is from February through March (Hay and McCarter 2000). Females lay between 7,000 and 60,000 eggs over sand, course gravel or detrital substrate. Eggs attach to gravel or sand and incubate for 30 to 40 days after which larvae drift to estuaries and coastal marine waters. In their first year of life, juveniles are found along the continental shelf (Wydoski and Whitney 1979; Gustafson 2016a). Adult eulachon are found in coastal and offshore marine habitats. With the exception of some individuals in Alaska, eulachon generally die after spawning (Gustafson 2016a). The maximum known lifespan is nine years of age, but 20 to 30 percent of individuals live to four years and most individuals survive to three years of age, although spawning has been noted as early as two years of age. Larval and post larval eulachon prey upon phytoplankton, copepods, copepod eggs, mysids, barnacle larvae, worm larvae, and other eulachon larvae until they reach adult size (WDFW and ODFW 2001). The primary prey of adult eulachon are copepods and euphausiids, malacostracans and cumaceans.

8.10.2 Population Dynamics

For most Southern DPS eulachon spawning runs, abundance is unknown with the exception of the Columbia and Fraser River spawning runs. Beginning in 1995, the Canada's Department of Fisheries and Oceans (DFO) started annual surveys in the Fraser River. These surveys consisted of estimating larval density, measuring river discharge, and using estimates of relative fecundity to determine spawning biomass (NMFS 2020). Beginning in 2011, Oregon Department of Fish and Wildlife (ODFW) and Washington Department of Fish and Wildlife (WDFW) began instituting similar monitoring in the Columbia River. From 2014 through 2018, the eulachon spawner population estimate for the Fraser River is 2,608,909 adults and for the Columbia River 16,188,081 adults (Table 6). The combined spawner estimate from the Columbia and Fraser rivers is 18,796,090 eulachon (NMFS 2020).

Table 6. Southern DPS eulachon spawning estimates for the lower Fraser River (British Columbia, Canada) and Columbia River (Oregon/Washington states, USA) (NMFS 2020).

	Fraser River		Columbia River	
Year	Biomass estimate (metric tons)	Estimated spawner population	Biomass estimate (metric tons)	Estimated spawner population
2011	31	765,445	723	17,860,400
2012	120	2,963,013	810	20,008,600
2013	100	2,469,177	1,845	45,546,700
2014	66	1,629,657	3,412	84,243,100
2015	317	7,827,292	2,330	57,525,700
2016	44	1,086,438	877	21,654,800
2017	35	864,212	330	8,148,600
2018	408	10,074,243	53	1,300,000
2014-2018	**106**	**2,608,009**	**656**	**16,188,081**

Southern DPS eulachon are genetically distinct from eulachon in the northern parts of its range (i.e., Alaska). Recent genetic analysis indicates that the Southern DPS exhibits a regional population structure, with a three-population southern Columbia-Fraser group, coming from the Cowlitz, Columbia, and Fraser rivers (Candy et al. 2015; Gustafson 2016a).

Adult and juvenile Southern DPS eulachon can be found in the Pacific Ocean, along the continental shelf, in waters from 50 to 200 m deep (Gustafson 2016a). Adults are most frequently found in the Columbia River and its tributaries (e.g., Cowlitz River, Sandy River), and sometimes in the Klamath River, California.

8.10.3 Status

Eulachon formerly experienced widespread, abundant runs and have been a staple of Native American diets for centuries along the northwest coast. However, runs that were formerly present in several California rivers as late as the 1960s and 1970s (i.e., Klamath River, Mad River and Redwood Creek) no longer occur (Larson and Belchik 2000). This decline likely began in the 1970s and continued until, in 1988 and 1989, the last reported sizeable run occurred in the Klamath River. No fish were found in 1996, although a moderate run was noted in 1999 (Moyle 2002b). Eulachon have not been identified in the Mad River and Redwood Creek since the mid-1990s (Moyle 2002b). The species is considered to be at moderate risk of extinction throughout its range because of a variety of factors, including predation, commercial and recreational fishing pressure (directed and bycatch), and loss of habitat. Warmer water temperatures associated with climate change could alter the timing of spawning, and the availability of prey for larval and juvenile eulachon (NMFS 2016e). Further population decline is anticipated to continue as a result of climate change and bycatch in commercial fisheries. However, because of their fecundity, eulachon are assumed to have the ability to recover quickly if given the opportunity (Bailey and Houde 1989).

8.10.4 Critical Habitat

On October 20, 2011, NMFS designated critical habitat for Southern DPS eulachon (76 FR 65324). Southern DPS eulachon critical habitat was discussed in Section 7.2.5.7.

8.10.5 Recovery Goals

See the 2017 Recovery Plan for the Southern DPS eulachon, for complete down listing/delisting criteria for each of their respective recovery goals (NMFS 2017f). The following items were the top recovery actions identified in the Recovery Plan:

- Implement outreach and education strategies.
- Conduct strategic research on eulachon.
- Develop biological viability targets.
- Conduct strategic research on eulachon habitats.
- Conduct research on threats, including in marine and freshwater habitat, bycatch, predation, dams and water diversions, water quality, and others.
- Assess regulatory measures, inadequacy of existing regulatory mechanisms.

- Develop a research, monitoring, evaluation, and adaptive management plan.

8.11 Sockeye Salmon – Ozette Lake ESU

This evolutionarily significant unit, or ESU, includes naturally spawned sockeye salmon originating from the Ozette River and Ozette Lake and its tributaries (Figure 14). In addition, sockeye salmon are bred in two artificial propagation programs.

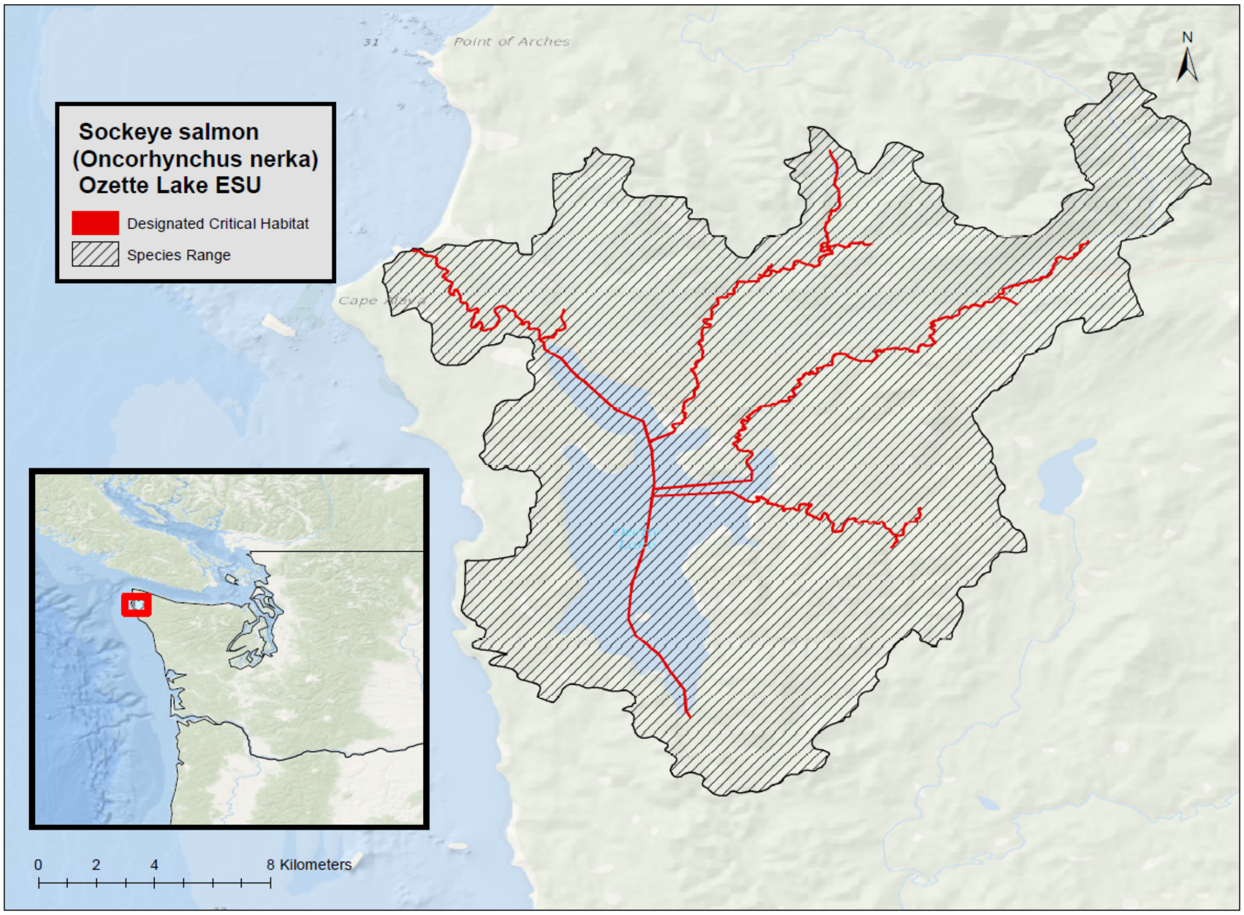

Figure 14. Range and Designated Critical Habitat of the Ozette Lake ESU of Sockeye Salmon.

The sockeye salmon is an anadromous species, although some sockeye spend their entire lives (about five years) in freshwater. Adult sockeye salmon are about three feet long and eight pounds. Sockeyes are bluish black with silver sides when they are in the ocean, and they turn bright red with a green head when they are spawning. On March 25, 1999, NMFS listed the Ozette Lake sockeye salmon ESU as threatened (64 FR 14528) and reaffirmed the ESU's status as threatened on June 28, 2005.

8.11.1 Life History

Most sockeye salmon exhibit a lake-type life history (i.e., they spawn and rear in or near lakes), though some exhibit a river-type life history. Spawning generally occurs in late summer and fall, but timing can vary greatly among populations. In lakes, sockeye salmon commonly spawn along "beaches" where underground seepage provides fresh oxygenated water. Females spawn in three to five redds over a couple of days. Incubation period is a function of water temperature and generally lasts 100 to 200 days (Burgner 1991). Sockeye salmon spawn once, generally in late summer and fall, and then die (semelparity).

Sockeye salmon fry primarily rear in lakes; river-emerged and stream-emerged fry migrate into lakes to rear. In the early fry stage from spring to early summer, juveniles forage exclusively in the warmer littoral (i.e., shoreline) zone where they depend mostly on fly larvae and pupae, copepods, and water fleas. Sub-yearling sockeye salmon move from the littoral habitat to a pelagic (i.e., open water) existence where they feed on larger zooplankton; however, flies may still make up a substantial portion of their diet. From one to three years after emergence, juvenile sockeye salmon generally rear in lakes, though some river-spawned sockeye may migrate to sea in their first year. Juvenile sockeye salmon feeding behaviors change as they transition through life stages after emergence to the time of smoltification. Distribution in lakes and prey preference is a dynamic process that changes daily and yearly depending on many factors including water temperature, prey abundance, presence of predators and competitors, and size of the juvenile. Peak emigration to the ocean occurs in mid-April to early May in southern sockeye populations (lower than 52ºN latitude) and as late as early July in northern populations (62ºN latitude) (Burgner 1991). Adult sockeye salmon return to their natal lakes to spawn after spending one to four years at sea. The diet of adult salmon consists of amphipods, copepods, squid and other fish.

8.11.2 Population Dynamics

The historical abundance of the Ozette Lake ESU of sockeye salmon is poorly documented, but may have been as high as 50,000 individuals (Blum 1988). Escapement estimates (run size minus broodstock take) from 1996 to 2006 range from a low of 1,404 in 1997 to a high of 6,461 in 2004, with a median of approximately 3,800 sockeye per year (geometric mean: 3,353) (Rawson et al. 2009). Current abundance estimates for Ozette Lake ESU sockeye salmon are presented in Table 7 below.

Table 7. Abundance Estimates for the Ozette Lake ESU of Sockeye Salmon (NMFS 2020).

Production	Life Stage	Abundance
Natural and Hatchery (Clipped and Intact Adipose)	Adult	5,036
Natural	Juvenile	1,037,787
Listed Hatchery Adipose Clipped	Juvenile	45,750
Listed Hatchery Intact Adipose	Juvenile	259,250

Productivity has fluctuated up and down over the last few decades, but overall appears to have remained stable (NWFSC 2015b). Given the degree of uncertainty in the abundance estimates, any interpretation of trends of small magnitude or over short time periods is speculative. (NWFSC 2015b).

For the Ozette Lake sockeye salmon ESU, the proportion of beach spawners is likely low; therefore, hatchery-originated fish are not likely to greatly affect the genetics of the naturally-spawned population. However, Ozette Lake sockeye have a relatively low genetic diversity compared to other sockeye salmon populations examined in Washington State (NWFSC 2015b). Genetic differences do occur among age cohorts. However, because different age groups do not reproduce together, the population may be more vulnerable to significant reductions in population structure due to catastrophic events or unfavorable conditions affecting a single year class.

The Ozette Lake sockeye salmon ESU is composed of one historical population with multiple spawning aggregations and two populations from the Umbrella Creek and Big River sockeye hatchery programs (NWFSC 2015b). Historically, at least four lake beaches were used for spawning; today only two beach spawning locations, Allen's and Olsen's Beaches, are used. Additionally, spawning occurs in the two tributaries of the hatchery programs (NWFSC 2015b). The Umbrella creek population is a large component of the total population (averaging over 50 percent for the last decade of data).

8.11.3 Status

NMFS listed the Ozette Lake sockeye salmon ESU because of habitat loss and degradation from the combined effects of logging, road building, predation, invasive plant species, and overharvest. Ozette Lake sockeye salmon have not been commercially harvested since 1982 and only minimally harvested by the Makah Tribe since 1982 (0 to 84 fish per year); there is no known marine fishing of this ESU. Overall abundance is substantially below historical levels, and whether the decrease in abundance is a result of fewer spawning aggregations, lower abundances in each aggregation, or a combination of both factors is unknown. Regardless, this ESU's viability has not improved, and the ESU would likely have a low resilience to additional perturbations. However, recovery potential for the Ozette Lake sockeye salmon ESU is good, particularly because of protections afforded it based on the lake's location within a Olympic National Park (NWFSC 2015b).

8.11.4 Critical Habitat

NMFS designated critical habitat for Ozette Lake sockeye salmon on September 2, 2005 (70 FR 52630). Critical habitat includes juvenile summer and winter rearing areas, juvenile migration corridors, areas for growth and development to adulthood, adult migration corridors, and spawning areas.

8.11.5 Recovery Goals

We adopted a recovery plan for Lake Ozette ESU sockeye salmon (NMFS 2009c) in May 2009. The criteria of the recovery plan were based upon Rawson et al. (2009). Recovery criteria include:

- Multiple, spatially distinct and persistent spawning aggregations throughout the historical range of the population (i.e., along the lake beaches and in one or more tributaries).
- One or more persistent spawning aggregations from each major genetic and life history group historically present. Also, genetic distinctness between anadromous sockeye, and kokanee salmon in the lake.
- Abundance between 31,250 and 121,000 adult spawners, over a number of years.

8.12 Sockeye Salmon – Snake River ESU

This evolutionarily significant unit, or ESU, includes naturally spawned anadromous and residual sockeye salmon originating from the Snake River basin (Figure 15), and also sockeye salmon from one artificial propagation program: Redfish Lake Captive Broodstock Program.

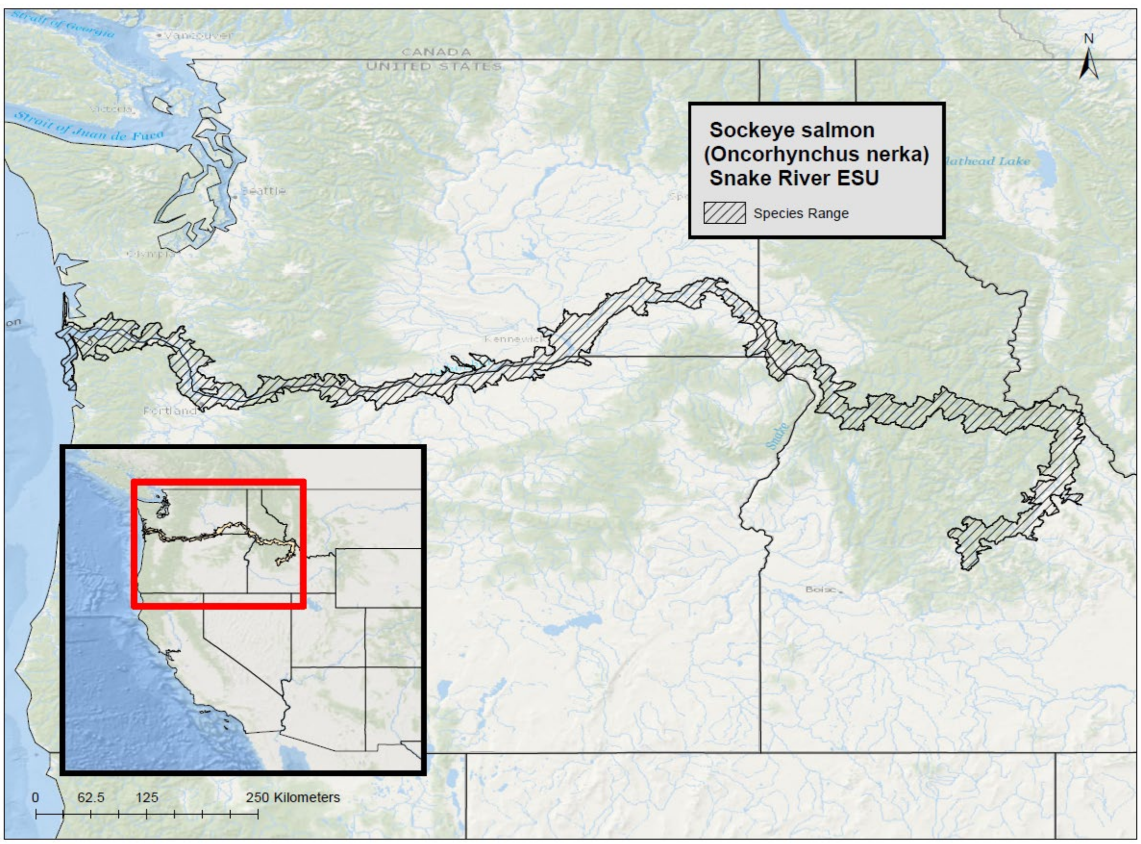

Figure 15. Geographic range of Sockeye salmon, Snake River ESU.

On November 20, 1991 NMFS listed the Snake River sockeye salmon ESU as endangered (56 FR 58619), and reaffirmed the ESU's status as endangered on June 28, 2005.

8.12.1 Life History

The life history for this ESU of sockeye salmon is the same as that presented in Section 8.11.1.

8.12.2 Population Dynamics

Adult returns over the last several years have ranged from a high of 1,579 fish in 2014 (including 453 natural-origin fish) to a low of 257 adults in 2012 (including 52 natural-origin fish). Sockeye salmon returns to Alturas Lake ranged from one fish in 2002 to 14 fish in 2010. No fish returned to Alturas Lake in 2012, 2013, or 2014 (NMFS 2015b). Current abundance estimates for the Snake River ESU of sockeye salmon are presented in Table 8 below.

Table 8. Current Abundance Estimates for Snake River ESU Sockeye Salmon (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	546
Natural	Juvenile	19,181
Listed Hatchery Adipose Clipped	Adult	4,004
Listed Hatchery Adipose Clipped	Juvenile	242,610

The large increases in returning adults in recent years reflect improved downstream and ocean survival as well as increases in juvenile production since the early 1990s. Although total sockeye salmon returns to the Sawtooth Valley in recent years have been high enough to allow for some level of natural spawning in Redfish Lake, the hatchery program remains at its initial phase with a priority on genetic conservation and building sufficient returns to support sustained outplanting and recolonization of the species' historic range (NMFS 2015b; NWFSC 2015b).

For the Snake River ESU, the Sawtooth Hatchery is focusing on genetic conservation. An overrepresentation of genes from the anadromous population in Redfish Lake exists, but inbreeding is low, which is a sign of a successful captive broodstock program (NMFS 2015b; NWFSC 2015b).

This ESU includes all anadromous and residual sockeye salmon from the Snake River basin, Idaho, and artificially-propagated sockeye salmon from the Redfish Lake Captive Broodstock Program (USDC 2014; NMFS 2015b; NWFSC 2015b). The Interior Columbia Technical Recovery Team (ICTRT) treats Sawtooth Valley Sockeye salmon as the single major population group (MPG) within the Snake River Sockeye Salmon ESU. The MPG contains one extant population (Redfish Lake) and two to four historical populations (Alturas, Petit, Stanley, and Yellowbelly Lakes) (NMFS 2015b). At the time of listing in 1991, the only confirmed extant population included in this ESU was the beach-spawning population of sockeye salmon from Redfish Lake, with about 10 fish returning per year (NMFS 2015b).

8.12.3 Status

The Snake River sockeye salmon ESU includes only one population comprised of all anadromous and residual sockeye salmon from the Snake River Basin, Idaho, as well as artificially propagated sockeye salmon from the Redfish Lake captive propagation program. Historical evidence indicates that the Snake River sockeye once had a range of life history patterns, with spawning populations present in several of the small lakes in the Sawtooth Basin. NMFS listed the Snake River sockeye salmon ESU because of habitat loss and degradation from the combined effects of damming and hydropower development, overexploitation, fisheries management practices, and poor ocean conditions. Recent effects of climate change, such as reduced stream flows and increased water temperatures, are limiting Snake River ESU productivity (NMFS 2015b; NWFSC 2015b). Adults produced through the captive propagation program currently support the entire ESU. This ESU is still at extremely high risk across all four basic risk measures (abundance, productivity, spatial structure, and diversity) and would likely have a very low resilience to additional perturbations. Habitat improvement projects have slightly decreased the risk to the species, but habitat concerns and water temperature issues remain. Overall, although the status of the Snake River sockeye salmon ESU appears to be improving, there is no indication that the biological risk category has changed (NWFSC 2015b).

8.12.4 Critical Habitat

NMFS designated critical habitat for Snake River sockeye salmon on December 28, 1993 (58 FR 68543). The critical habitat encompasses the waters, waterway bottoms, and adjacent riparian zones of specified lakes and river reaches in the Columbia River that are or were accessible to salmon of this ESU (except reaches above impassable natural falls, and Dworshak and Hells Canyon Dams).

8.12.5 Recovery Goals

See the 2015 recovery plan for the Snake River sockeye salmon ESU for complete down-listing/delisting criteria for recovery goals for the species (NMFS 2015b). Broadly, recovery plan goals emphasize restoring historical lake populations and improving water quality and quantity in lakes and migration corridors.

8.13 Steelhead Trout – California Central Valley DPS

The Central Valley DPS of steelhead includes naturally spawned anadromous steelhead trout originating below natural and manmade impassable barriers from the Sacramento and San Joaquin Rivers and their tributaries and excludes such fish originating from San Francisco and San Pablo Bays and their tributaries (Figure 16). Further, the Central Valley DPS of steelhead trout includes steelhead from two artificial propagation programs.

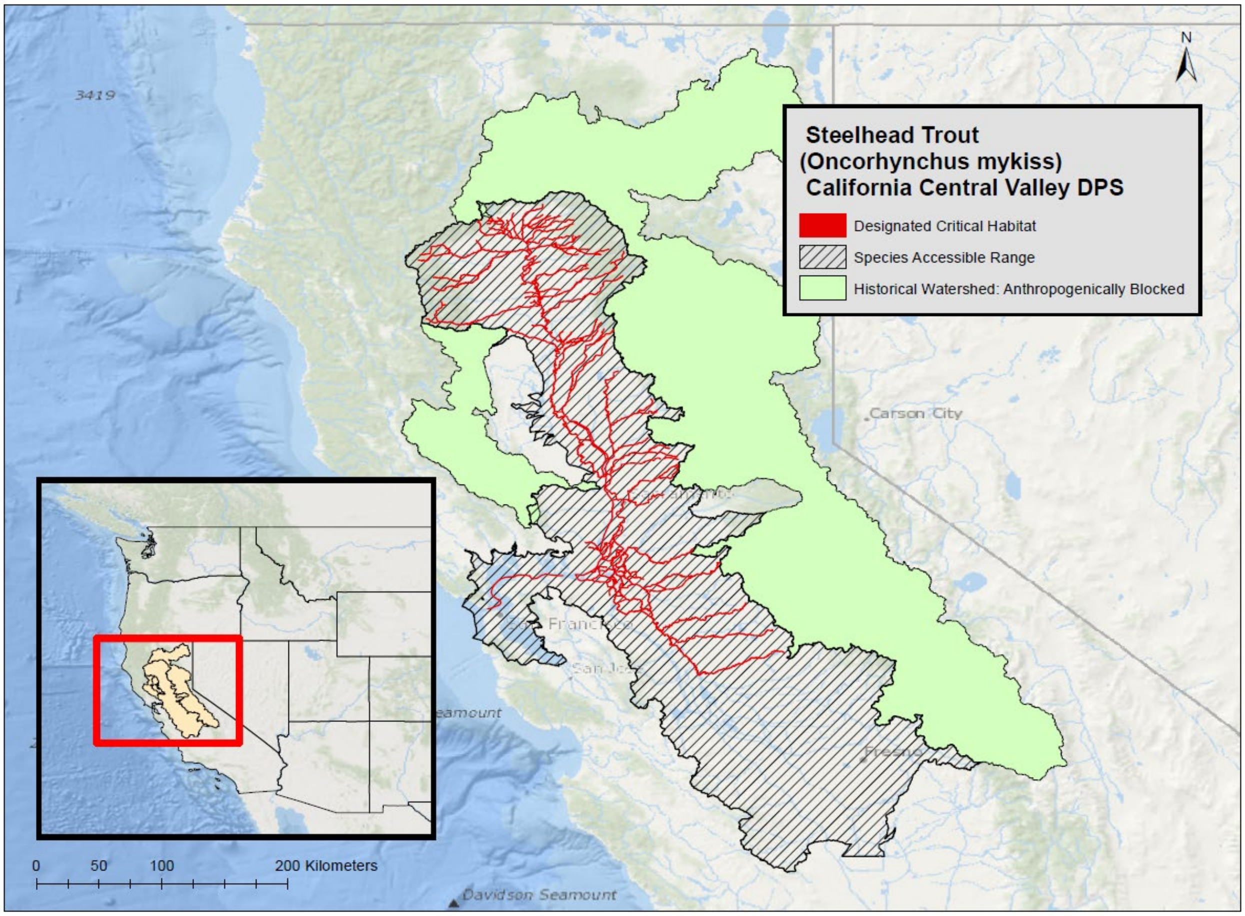

Figure 16. Geographic range and designated critical habitat of California Central Valley Steelhead.

On March 19, 1998 NMFS listed the California Central Valley DPS of steelhead as threatened (63 FR 13347) and reaffirmed the DPS's status as threatened on January 5, 2006 (71 FR 834).

8.13.1 Life History

The Central Valley DPS of steelhead spawn downstream of dams on every major tributary within the Sacramento and San Joaquin River systems. The female steelhead selects a site with good intergravel flow, digs a redd with her tail, usually in the coarse gravel of the tail of a pool or in a riffle, and deposits eggs while an attendant male fertilizes them. The preferred water temperature range for steelhead spawning is reported to be 30°F to 52°F (CDFW 2000). The eggs hatch in three to four weeks at 50°F to 59°F, and fry emerge from the gravel four to six weeks later (Shapovalov and Taft 1954). Regardless of life history strategy, for the first year or two of life steelhead are found in cool, clear, fast flowing permanent streams and rivers where riffles predominate over pools, there is ample cover from riparian vegetation or undercut banks, and invertebrate life is diverse and abundant (Moyle 2002b). The smallest fish are most often found in riffles, intermediate size fish in runs, and larger fish in pools.

Steelhead typically migrate to marine waters after spending two years in freshwater. They reside in marine waters for typically two or three years prior to returning to their natal stream to spawn as four- or five-year olds. Unlike Pacific salmon, steelhead are capable of spawning more than once before they die. However, it is rare for steelhead to spawn more than twice before dying, and most that do so are females (Moyle 2002b). Currently, Central Valley steelhead are considered "ocean-maturing" (also known as winter) steelhead, although summer steelhead may have been present prior to construction of large dams (Moyle 2002b). Ocean maturing steelhead enter freshwater with well-developed gonads and spawn shortly after river entry. Central Valley steelhead enter freshwater from August through April. They hold until flows are high enough in tributaries to enter for spawning (Moyle 2002b). Steelhead adults typically spawn from December through April, with peaks from January through March in small streams and tributaries where cool, well oxygenated water is available year-round (Hallock et al. 1961; McEwan 2001).

8.13.2 Population Dynamics

Historic Central Valley steelhead run size may have approached one to two million adults annually (McEwan 2001). By the early 1960s, the steelhead run size had declined to about 40,000 adults (McEwan 2001). Over the past 30 years, the naturally spawned steelhead populations in the upper Sacramento River have declined substantially. Based on catch ratios at Chipps Island in the Delta and using some generous assumptions regarding survival, the average number of Central Valley steelhead females spawning naturally in the entire Central Valley during the years 1980 to 2000 was estimated at about 3,600 (Good et al. 2005). Current abundance estimates for the California Central Valley ESU of steelhead trout are presented in Table 9 below.

Table 9. Current Abundance Estimates for the California Central Valley ESU of Steelhead Trout (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	1,686
Natural	Juvenile	630,403
Listed Hatchery Adipose Clipped	Adult	3,856
Listed Hatchery Adipose Clipped	Juvenile	1,600,653

California Central Valley steelhead lack annual monitoring data for calculating trends. However, the Red Bluff Diversion Dam counts and redd counts up to 1993 and later sporadic data show that the DPS has had a significant long-term downward trend in abundance (NMFS 2009a).

The Central Valley steelhead distribution ranges over a wide variety of environmental conditions and likely contains biologically significant amounts of spatially structured genetic diversity (Lindley et al. 2006). The loss of populations and reduction in abundances have reduced the large diversity that existed within the DPS. The genetic diversity of the majority of steelhead spawning runs within this DPS is also compromised by hatchery-origin fish.

Central Valley steelhead spawn downstream of dams on every major tributary within the Sacramento and San Joaquin River systems.

8.13.3 Status

Many watersheds in the Central Valley are experiencing decreased abundance of California Central Valley steelhead. Dam removal and habitat restoration efforts in Clear Creek appear to be benefiting steelhead as recent increases in non-clipped (wild) abundance have been observed. Despite the positive trend in Clear Creek, all other concerns raised in the previous status review remain, including low adult abundances, loss and degradation of a large percentage of the historic spawning and rearing habitat, and domination of smolt production by hatchery fish. Many other planned restoration and reintroduction efforts have yet to be implemented or completed, or are focused on Chinook salmon, and have yet to yield demonstrable improvements in habitat, let alone documented increases in naturally produced steelhead. There are indications that natural production of steelhead continues to decline and is now at a very low level. Their continued low numbers in most hatcheries, and domination by hatchery fish, makes the continued existence of naturally reproduced steelhead a concern. California Central Valley steelhead is likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

8.13.4 Critical Habitat

NMFS designated critical habitat for California Central Valley steelhead on September 2, 2005 (70 FR 52488). Critical habitat includes freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and estuarine areas.

8.13.5 Recovery Goals

See the 2014 recovery plan for the California Central Valley steelhead DPS for complete down-listing/delisting criteria for recovery goals for the species (NMFS 2014b). The delisting criteria for this DPS are:

- One population in the Northwestern California Diversity Group at low risk of extinction
- Two populations in the Basalt and Porous Lava Flow Diversity Group at low risk of extinction
- Four populations in the Northern Sierra Diversity Group at low risk of extinction
- Two populations in the Southern Sierra Diversity Group at low risk of extinction
- Maintain multiple populations at moderate risk of extinction.

8.14 Steelhead Trout – Central California Coast DPS

The Central California Coast DPS of Steelhead trout includes all naturally spawned populations of steelhead (and their progeny) in streams from the Russian River to Aptos Creek, Santa Cruz

County, California (inclusive). It also includes the drainages of San Francisco and San Pablo Bays (Figure 17).

On August 18, 1997 NMFS listed the Central California Coast DPS of steelhead as threatened (62 FR 43937) and reaffirmed the DPS's status as threatened on January 5, 2006 (71 FR 834).

8.14.1 Life History

The Central California Coast DPS of steelhead is entirely composed of winter-run fish. Adults return to the Russian River and migrate upstream from December to April, and smolts emigrate between March and May (Shapovalov and Taft 1954; Hayes et al. 2004). Most spawning takes place from January through April. The life history for this DPS of steelhead trout is the same that is presented in Section 8.13.1.

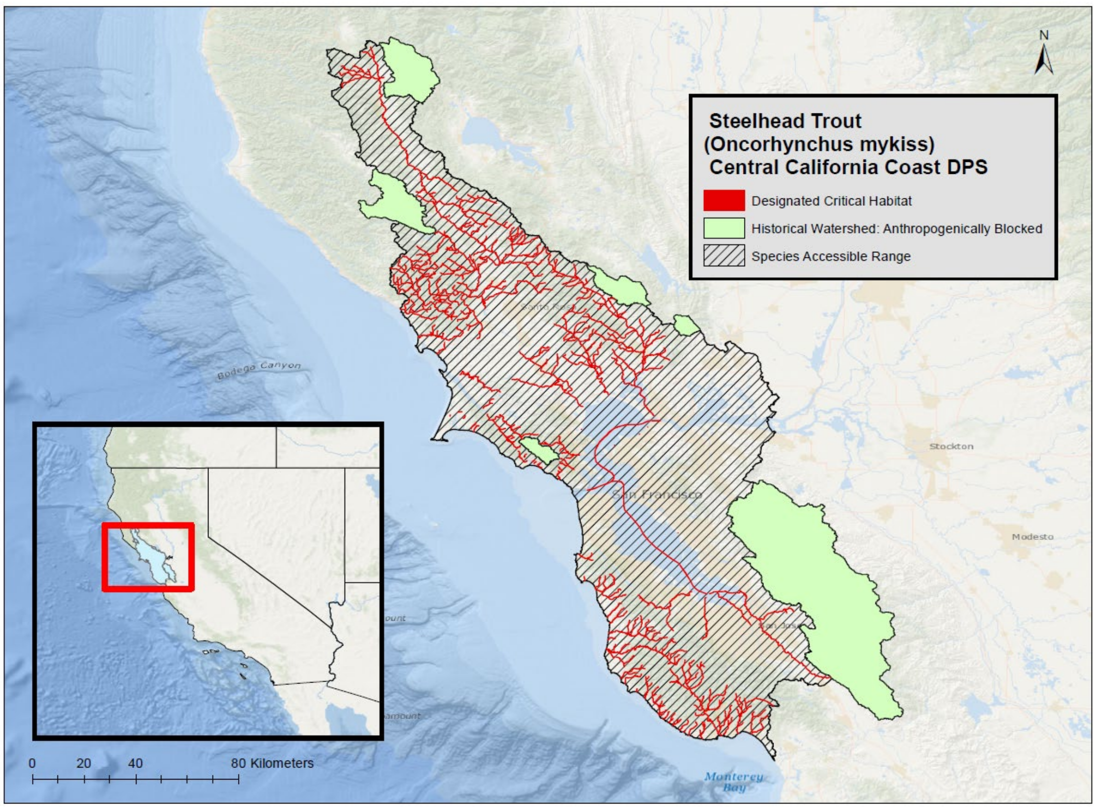

Figure 17. Geographic range and designated critical habitat of Central California Coast Steelhead.

Steelhead typically migrate to marine waters after spending two years in freshwater. They reside in marine waters for typically two or three years prior to returning to their natal stream to spawn as four- or five-year olds. Unlike Pacific salmon, steelhead are capable of spawning more than once before they die. However, it is rare for steelhead to spawn more than twice before dying, and most that do so are females (Moyle 2002b).While age of smoltification typically ranges for one to four years, recent studies indicate that growth rates in Soquel Creek likely prevent juveniles from undergoing smoltification until age two (Sogard et al. 2009).

8.14.2 Population Dynamics

Historically, the entire Central California Coast steelhead DPS may have consisted of an average runs size of 94,000 adults in the early 1960s (Good et al. 2005). Current abundance estimates for the California Central Coast ESU of steelhead trout are presented in Table 10 below. Presence-absence data indicate that most (82 percent) sampled streams (a subset of all historical steelhead streams) had extant populations of juvenile *O. mykiss* (Adams 2000; Good et al. 2005).

Table 10. Current Abundance Estimates for the California Central Coast ESU of Steelhead Trout (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	2,187
Natural	Juvenile	248,771
Listed Hatchery Adipose Clipped	Adult	3,866
Listed Hatchery Adipose Clipped	Juvenile	648,891

Though the information for individual populations is limited, available information strongly suggests that no population is viable. Long-term population sustainability is extremely low for the southern populations in the Santa Cruz mountains and in the San Francisco Bay (NMFS 2008a). Declines in juvenile southern populations are consistent with the more general estimates of declining abundance in the region (Good et al. 2005).

The interior Russian River winter-run steelhead has the largest runs with an estimate of an average of over 1,000 spawners. Due to this, Russian River winter-run steelhead may be able to be sustained over the long-term but hatchery management has eroded the population's genetic diversity (Bjorkstedt et al. 2005; NMFS 2008a).

8.14.3 Status

The Central California Coast steelhead consisted of nine historic functionally independent populations and 23 potentially independent populations (Bjorkstedt et al. 2005). Of the historic functionally independent populations, at least two are extirpated while most of the remaining are nearly extirpated. Current runs in the basins that originally contained the two largest steelhead populations for the DPS, the San Lorenzo and the Russian Rivers, both have been estimated at less than 15 percent of their abundances just 30 years earlier (Good et al. 2005). The Russian River is of particular importance for preventing the extinction and contributing to the recovery of Central California Coast steelhead (NOAA 2013b). Steelhead access to significant portions of the upper Russian River has also been blocked (Busby et al. 1996a; NMFS 2008a).

8.14.4 Critical Habitat

Critical habitat was designated for this species on September 2, 2005 (70 FR 52630). Critical habitat includes freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and estuarine areas.

8.14.5 Recovery Goals

See the 2016 recovery plan for the Central California Coast steelhead DPS for complete down-listing/delisting criteria for recovery goals for the species. Recovery plan objectives are to:

- Reduce the present or threatened destruction, modification, or curtailment of habitat or range;
- Ameliorate utilization for commercial, recreational, scientific, or educational purposes;
- Abate disease and predation;
- Establish the adequacy of existing regulatory mechanisms for protecting Central California Coast steelhead now and into the future (i.e., post-delisting);
- Address other natural or manmade factors affecting the continued existence of Central California Coast steelhead;
- Ensure Central California Coast steelhead status is at a low risk of extinction based on abundance, growth rate, spatial structure and diversity.

8.15 Steelhead Trout – Lower Columbia River DPS

The Lower Columbia River DPS of steelhead trout includes naturally spawned steelhead originating below natural and manmade impassable barriers from rivers between the Cowlitz and Wind Rivers (inclusive) and the Willamette and Hood Rivers (inclusive) and excludes such fish originating from the upper Willamette River basin above Willamette Falls (Figure 18). The Lower Columbia River DPS also includes steelhead from seven artificial propagation programs.

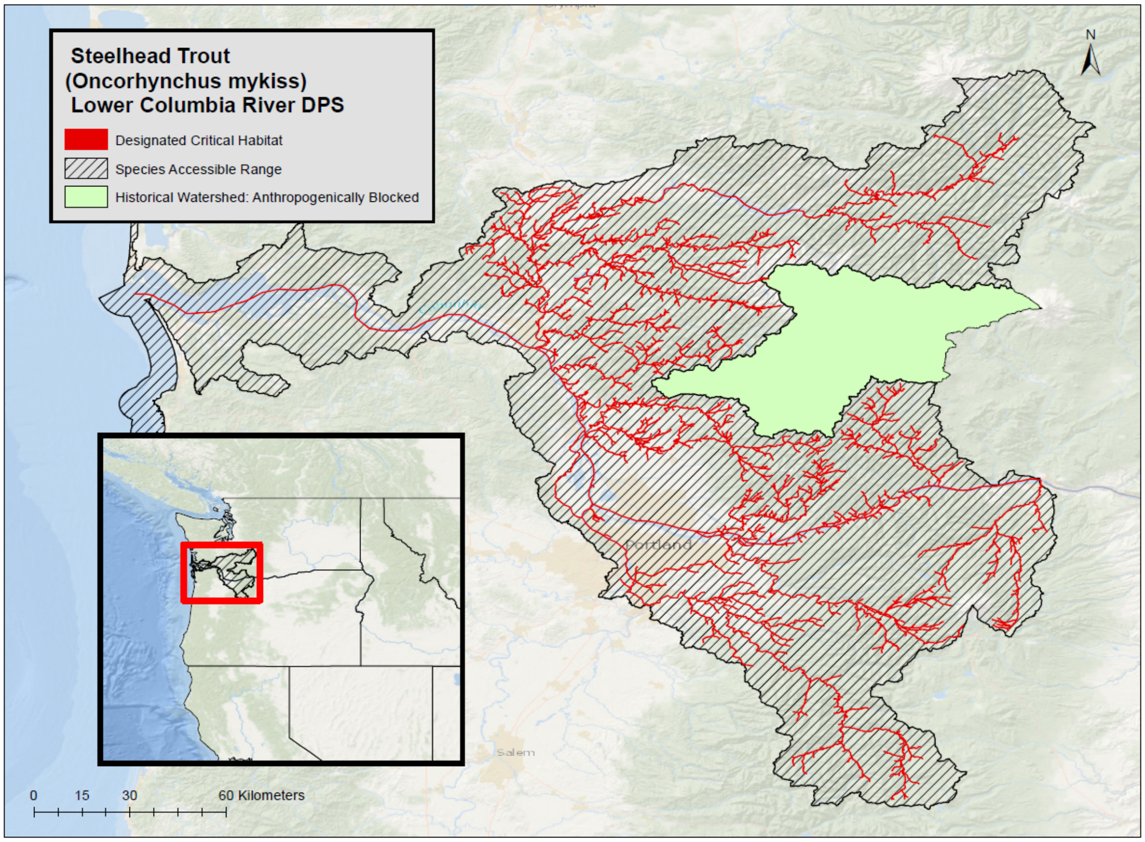

Figure 18. Geographic range and designated critical habitat of Lower Columbia River steelhead.

On March 19, 1998, NMFS listed the Lower Columbia River DPS of steelhead as threatened (63 FR 13347) and reaffirmed the DPS's status as threatened on January 5, 2006 (71 FR 834).

8.15.1 Life History

The Lower Columbia River steelhead DPS includes both summer- and winter-run stocks. Summer-run steelhead return sexually immature to the Columbia River from May to November, and spend several months in freshwater prior to spawning. Winter-run steelhead enter freshwater from November to April, are close to sexual maturation during freshwater entry, and spawn shortly after arrival in their natal streams. Where both races spawn in the same stream, summer-run steelhead tend to spawn at higher elevations than the winter-run. The life history for this DPS of steelhead trout is the same as that presented in Section 8.13.1.

The majority of juvenile lower Columbia River steelhead remain for two years in freshwater environments before ocean entry in spring. Both winter- and summer-run adults normally return after two years in the marine environment. Unlike Pacific salmon, steelhead are capable of spawning more than once before they die. However, it is rare for steelhead to spawn more than twice before dying, and most that do so are females (Moyle 2002b).

8.15.2 Population Dynamics

The Winter-run Western Cascade MPG includes native winter-run steelhead in 14 demographically independent populations (DIPs) from the Cowlitz River to the Washougal River. Abundances have remained fairly stable and have remained low, averaging in the hundreds of fish. Notable exceptions to this were the Clackamas and Sandy River winter-run steelhead populations, that are exhibiting recent rises in natural-origin returns abundance and maintaining low levels of hatchery-origin steelhead on the spawning grounds (NWFSC 2015b). In the Summer-run Cascade MPG, there are four summer-run steelhead populations. Absolute abundances have been in the hundreds of fish. In the Winter-run Gorge MPG both the Lower and Upper Gorge population surveys for winter steelhead are very limited and abundance levels in the Hood River have been low but relatively stable. In the Summer-run Gorge MPG adult abundance in the Wind River remains stable, but at a low level (hundreds of fish). Current abundance estimates for the Lower Columbia River DPS of steelhead trout are presented in Table 11 below.

Table 11. Current Abundance Estimates for the Lower Columbia River DPS of Steelhead Trout (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	12,920
Natural	Juvenile	352,146
Listed Hatchery Adipose Clipped and Intact	Adult	22,297
Listed Hatchery Adipose Clipped	Juvenile	1,197,156
Listed Hatchery Intact Adipose	Juvenile	9,138

Population trends for the Winter-run Western Cascade MPG are fairly stable. Long- and short-term trends for three independent populations within the Summer-run Cascade MPG are positive; though the 2014 surveys indicate a drop in abundance for all three. Population trends in the Winter-run Gorge MPG is relatively stable. The overall status of the Summer-run Gorge MPG is uncertain.

Total steelhead hatchery releases in the Lower Columbia River Steelhead DPS have decreased since the last status review, declining from a total (summer and winter run) release of approximately 3.5 million to 3 million from 2008 to 2014. Some populations continue to have relatively high fractions of hatchery-origin spawners, whereas others (e.g., Wind River) have relatively few hatchery origin spawners.

There are four MPGs comprised of 23 DIPs, including six summer-run steelhead populations and 17 winter-run populations (NWFSC 2015b). Summer steelhead spawning areas in the Lower

Columbia River are found above waterfalls and other features that create seasonal barriers to migration. There have been a number of large-scale efforts to improve accessibility (one of the primary metrics for spatial structure) in this ESU. Trap and haul operations were begun on the Lewis River in 2012 for winter-run steelhead, reestablishing access to historically occupied habitat above Swift Dam. In 2014, 1033 adult winter steelhead (integrated program fish) were transported to the upper Lewis River; however, juvenile collection efficiency is still below target levels. In addition, there have been a number of recovery actions throughout the ESU to remove or improve culverts and other small-scale passage barriers.

8.15.3 Status

The Lower Columbia River steelhead had 17 historically independent winter steelhead populations and six independent summer steelhead populations (McElhany et al. 2003; Myers et al. 2006). All historic Lower Columbia River steelhead populations are considered extant. However, spatial structure within the historically independent populations, especially on the Washington side, has been substantially reduced by the loss of access to the upper portions of some basins due to tributary hydropower development. The majority of winter-run steelhead populations in this DPS continue to persist at low abundances (NWFSC 2015b). Hatchery interactions remain a concern in select basins, but the overall situation is somewhat improved compared to prior reviews. Summer-run steelhead DIPs were similarly stable, but at low abundance levels. Habitat degradation continues to be a concern for most populations. Even with modest improvements in the status of several winter-run populations, none of the populations appear to be at fully viable status, and similarly none of the MPGs meet the criteria for viability. The DPS therefore continues to be at moderate risk (NWFSC 2015b).

8.15.4 Critical Habitat

Critical habitat was designated for the Lower Columbia River steelhead on September 2, 2005. Critical habitat includes freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and estuarine areas.

8.15.5 Recovery Goals

The Lower Columbia River DPS of steelhead are included in the Lower Columbia River recovery plan (NMFS 2013a). For this DPS, threats in all categories must be reduced, but the most crucial elements are protecting favorable tributary habitat and restoring habitat in the Upper Cowlitz, Cispus, North Fork Toutle, Kalama and Sandy subbasins (for winter steelhead), and the East Fork Lewis, and Hood, subbasins (for summer steelhead). Protection and improvement is also need among the South Fork Toutle and Clackamas winter steelhead populations.

8.16 Steelhead Trout – Middle Columbia River DPS

The Middle Columbia River DPS of steelhead trout includes naturally spawned anadromous steelhead originating below natural and manmade impassable barriers from the Columbia River and its tributaries upstream of the Wind and Hood Rivers (exclusive) to and including the

Yakima River and excludes such fish originating from the Snake River Basin (Figure 19). Further, this DPS includes steelhead from seven artificial propagation programs.

On March 25, 1999 NMFS listed the Middle Columbia River (MCR) DPS of steelhead as threatened (64 FR 14517) and reaffirmed the DPS's status as threatened on January 5, 2006 (71 FR 834).

8.16.1 Life History

Middle Columbia River steelhead populations are mostly of the summer-run type. Adult steelhead enter freshwater from June through August. The only exceptions are populations of inland winter-run steelhead which occur in the Klickitat River and Fifteenmile Creek (Busby et al. 1996a). The life history for this DPS of steelhead trout is the same as that presented in Section 8.13.1.

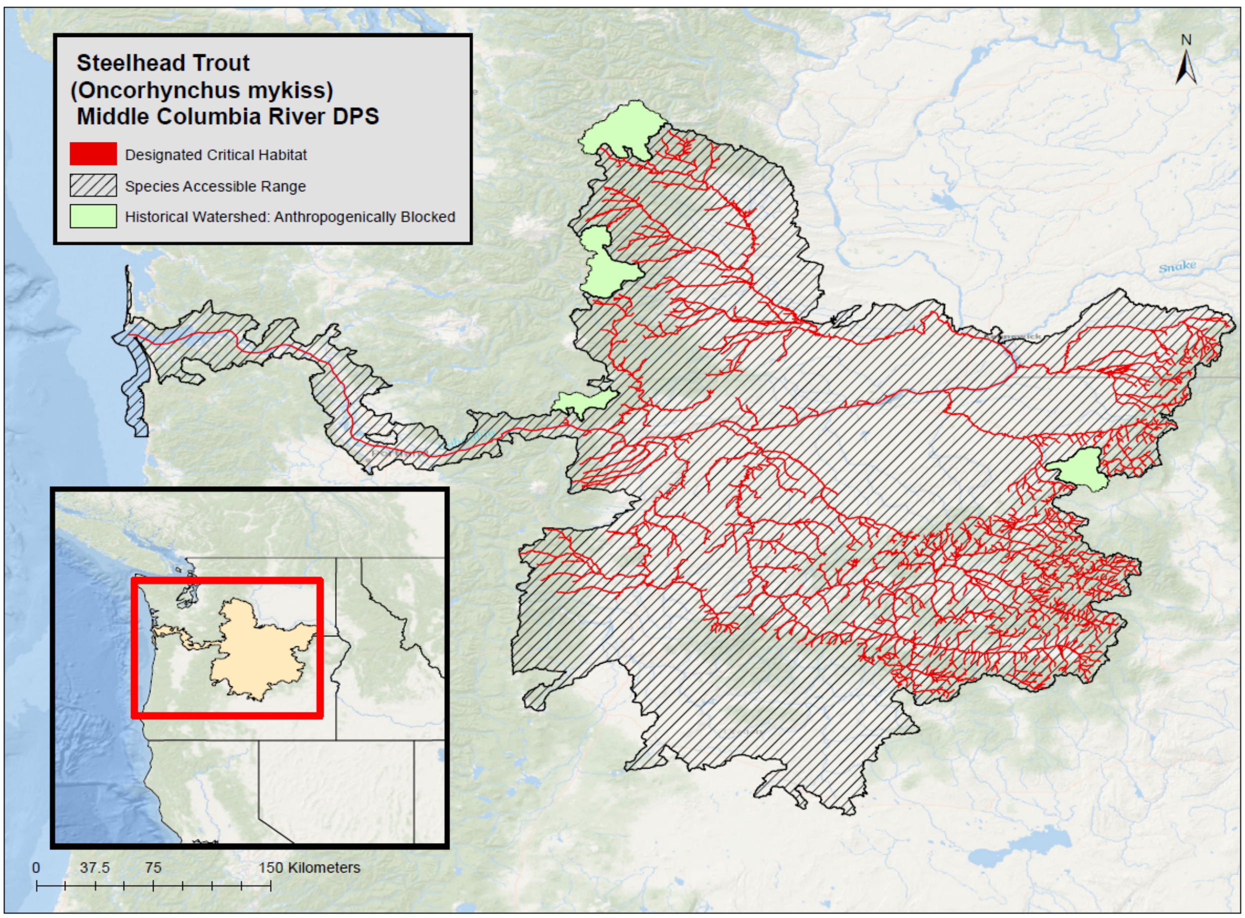

Figure 19. Geographic range and designated critical habitat of Middle Columbia River steelhead.

The majority of juveniles smolt and out-migrate as two-year olds. Most of the rivers in this region produce about equal or higher numbers of adults having spent one year in the ocean as adults having spent two years. However, summer-run steelhead in Klickitat River have a life cycle more like LCR steelhead whereby the majority of returning adults have spent two years in the ocean (Busby et al. 1996a). Adults may hold in the river up to a year before spawning. Unlike Pacific salmon, steelhead are capable of spawning more than once before they die. However, it is rare for steelhead to spawn more than twice before dying, and most that do so are females (Moyle 2002b).

8.16.2 Population Dynamics

Historic run estimates for the Yakima River imply that annual species abundance may have exceeded 300,000 returning adults (Busby et al. 1996a). The five-year average (geometric mean) return of natural Middle Columbia River steelhead for 1997 to 2001 was up from basin estimates of previous years. Returns to the Yakima River, the Deschutes River, and sections of the John Day River system were substantially higher compared to 1992 to 1997 (Good et al. 2005). The five-year average for these basins is 298 and 1,492 fish, respectively (Good et al. 2005). Current abundance estimates for the Middle Columbia River DPS of steelhead trout are presented in Table 12 below.

Table 12. Current Abundance Estimates for the Middle Columbia River DPS of Steelhead Trout (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	5,052
Natural	Juvenile	407,697
Listed Hatchery Adipose Clipped	Adult	448
Listed Hatchery Adipose Clipped	Juvenile	444,973
Listed Hatchery Intact Adipose	Adult	112
Listed Hatchery Intact Adipose	Juvenile	110,469

There have been improvements in the viability ratings for some of the component populations, but the Middle Columbia River Steelhead DPS is not currently meeting the viability criteria described in the Mid-Columbia Steelhead Recovery Plan.

The ICTRT identified 17 extant populations in this DPS (ICTRT 2003; McClure et al. 2005). The populations fall into four MPGs: Cascade eastern slope tributaries (five extant and two extirpated populations), the John Day River (five extant populations), the Walla Walla and Umatilla rivers (three extant and one extirpated populations), and the Yakima River (four extant populations).

8.16.3 Status

Within the Middle Columbia River DPS of steelhead, the ICTRT identified 16 extant populations in four MPGs (Cascades Eastern Slopes Tributaries, John Day River, Walla Walla and Umatilla Rivers, and Yakima River) and one unaffiliated independent population (Rock Creek) (ICTRT

2003). There are two extinct populations in the Cascades Eastern Slope MPG: the White Salmon River and the Deschutes Crooked River above the Pelton/Round Butte Dam complex. Present population structure is delineated largely on geographical proximity, topography, distance, ecological similarities or differences. Using criteria for abundance and productivity, the ICTRT modeled a gaps analysis for each of the four MPGs in this DPS under three different ocean conditions and a base hydro condition (most recent 20-year survival rate). The results showed that none of the MPGs would be able to achieve a 5 percent or less risk of extinction over 100 years without recovery actions. It is important to consider that significant gaps in factors affecting spatial structure and diversity also contribute to the risk of extinction for these fish.

8.16.4 Critical Habitat

Critical habitat was designated for this species on September 2, 2005 (70 FR 52630). Critical habitat includes freshwater spawning sites, freshwater rearing sites, and freshwater migration corridors.

8.16.5 Recovery Goals

See the 2009 recovery plan for the Middle Columbia River steelhead DPS for complete down-listing/delisting criteria for recovery goals for the species with criteria based on biological viability outlining the thresholds for each MPG, including abundance and productivity thresholds, as well as spatial structure and diversity criteria (NMFS 2009b).

8.17 Steelhead Trout – Northern California DPS

The Northern California DPS of steelhead trout includes naturally spawned steelhead originating below natural and manmade impassable barriers in California coastal river basins from Redwood Creek to and including the Gualala River (Figure 21).

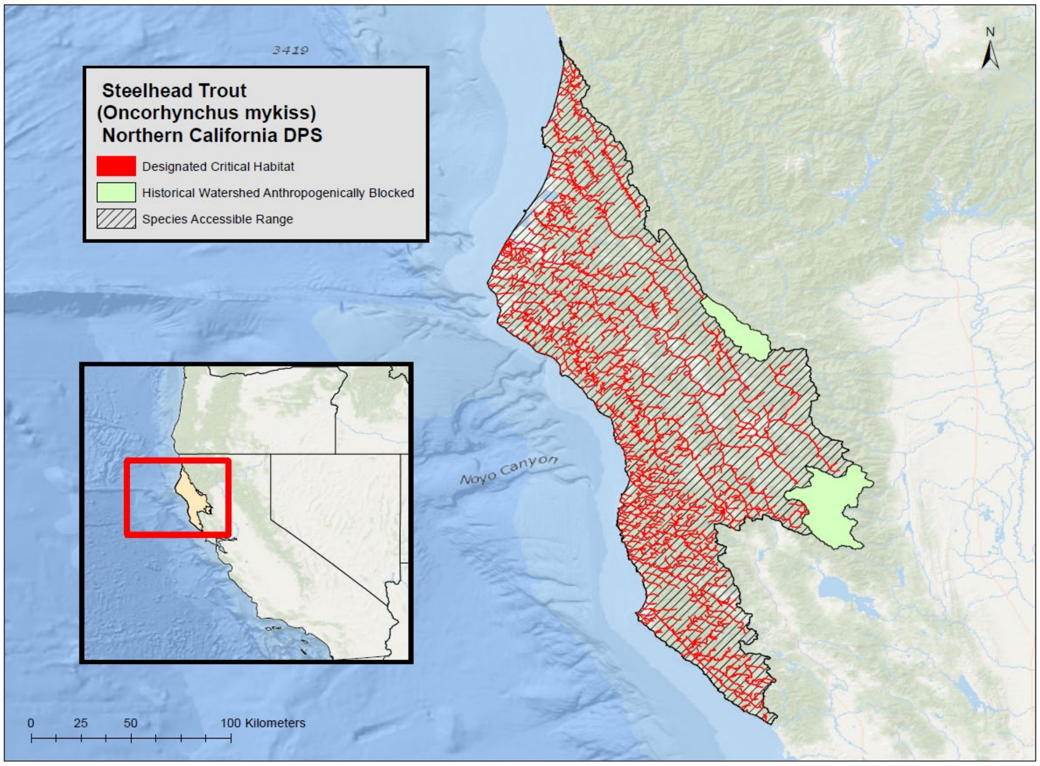

Figure 20. Geographic range and designated critical habitat of Northern California DPS steelhead.

On June 7, 2000 NMFS listed the Northern California DPS of steelhead as threatened (65 FR 36074) and reaffirmed the DPS's status as threatened on January 5, 2006 (71 FR 834).

8.17.1 Life History

The Northern California DPS of steelhead includes both winter- and summer –run steelhead. In the Mad and Eel Rivers, immature steelhead may return to freshwater as "half-pounders" after spending only two to four months in the ocean. Generally, a half-pounder will overwinter in freshwater and return to the ocean in the following spring.

Juvenile out-migration appears more closely associated with size than age but generally, throughout their range in California, juveniles spend two years in freshwater (Busby et al. 1996a). Smolts range from 14 to 21 cm in length. Juvenile steelhead may migrate to rear in lagoons throughout the year with a peak in the late spring/early summer and in the late fall/early winter period (Shapovalov and Taft 1954; Zedonis 1992).

Steelhead spend anywhere from one to five years in salt water, however, two to three years are most common (Busby et al. 1996a). Ocean distribution is not well known but coded wire tag recoveries indicate that most Northern California steelhead migrate north and south along the continental shelf (Barnhart 1986).

8.17.2 Population Dynamics

Most populations for which there are population estimates available remain well below viability targets; however, the short-term increases observed for many populations, despite the occurrence of a prolonged drought in northern California, suggests this DPS is not at immediate risk of extinction. Current abundance estimates for the Northern California DPS of steelhead trout are presented in Table 14 below.

Table 13. Current Abundance Estimates for the Northern California DPS of Steelhead Trout (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	7,221
Natural	Juvenile	821,389

Overall, the available data for winter-run populations— predominately in the North Coastal, North-Central Coastal, and Central Coastal strata— indicate that all populations are well below viability targets, most being between five percent and 13 percent of these goals. For the two Mendocino Coast populations with the longest time series, Pudding Creek and Noyo River, the 13-year trends have been negative and neutral, respectively (Spence 2016). However, the short-term (six-year) trend has been generally positive for all independent populations in the North-Central Coastal and Central Coastal strata, including the Noyo River and Pudding Creek (Spence 2016). Data from Van Arsdale Station likewise suggests that, although the long-term trend has been negative, run sizes of natural-origin steelhead have stabilized or are increasing (Spence 2016). Thus, we have no strong evidence to indicate conditions for winter-run populations in the DPS have worsened appreciably since the last status review (Williams et al. 2011). Summer-run populations continue to be of significant concern because of how few populations currently exist. The Middle Fork Eel River population has remained remarkably stable for nearly five decades and is closer to its viability target than any other population in the DPS (Spence 2016). Although the time series is short, the Van Duzen River appears to be supporting a population numbering in the low hundreds. However, the Redwood Creek and Mattole River populations appear small, and little is known about other populations including the Mad River and other tributaries of the Eel River (i.e., Larabee Creek, North Fork Eel, and South Fork Eel).

Artificial propagation was identified as negatively affecting wild stocks of salmonids through interactions with non-native fish, introductions of disease, genetic changes, competition for space and food resources, straying and mating with native populations, loss of local genetic adaptations, mortality associated with capture for broodstock and palliating the destruction of habitat and concealing problems facing wild stocks.

8.17.3 Status

The available data for winter-run populations— predominately in the North Coastal, North-Central Coastal, and Central Coastal strata— indicate that all populations are well below viability targets, most being between five percent and 13 percent of these goals. For the two Mendocino Coast populations with the longest time series, Pudding Creek and Noyo River, the 13-year trends have been negative and neutral, respectively (Spence 2016). However, the short-term (six-year) trend has been generally positive for all independent populations in the North-Central Coastal and Central Coastal strata, including the Noyo River and Pudding Creek (Spence 2016). Data from Van Arsdale Station likewise suggests that, although the long-term trend has been negative, run sizes of natural-origin steelhead have stabilized or are increasing (Spence 2016). Thus, we have no strong evidence to indicate conditions for winter-run populations in the DPS have worsened appreciably since the last status review (Williams et al. 2011). Summer-run populations continue to be of significant concern because of how few populations currently exist. The Middle Fork Eel River population has remained remarkably stable for nearly five decades and is closer to its viability target than any other population in the DPS (Spence 2016). Although the time series is short, the Van Duzen River appears to be supporting a population numbering in the low hundreds. However, the Redwood Creek and Mattole River populations appear small, and little is known about other populations including the Mad River and other tributaries of the Eel River (i.e., Larabee Creek, North Fork Eel, and South Fork Eel). Most populations for which there are population estimates available remain well below viability targets; however, the short-term increases observed for many populations, despite the occurrence of a prolonged drought in northern California, suggests this DPS is not at an immediate risk of extinction.

8.17.4 Critical Habitat

NMFS designated critical habitat for Northern California DPS steelhead on September 2, 2005. Critical habitat includes freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and estuarine areas.

8.17.5 Recovery Goals

See the 2016 recovery plan for the Northern California steelhead DPS for complete down-listing/delisting criteria for recovery goals for the DPS (NMFS 2016f).

8.18 Steelhead Trout – Puget Sound DPS

This DPS includes naturally spawned anadromous *O. mykiss* (steelhead) originating below natural and manmade impassable barriers from rivers flowing into Puget Sound from the Elwha River (inclusive) eastward, including rivers in Hood Canal, South Sound, North Sound and the Georgia Strait (Figure 22). The DPS also includes steelhead from six artificial propagation programs. On May 11, 2007 NMFS listed the Puget Sound DPS of steelhead as threatened (72 FR 26722).

8.18.1 Life History

The Puget Sound steelhead DPS contains both winter-run and summer-run steelhead. Adult winter-run steelhead generally return to Puget Sound tributaries from December to April (NMFS 2005). Spawning occurs from January to mid-June, with peak spawning occurring from mid-April through May. Prior to spawning, maturing adults hold in pools or in side channels to avoid high winter flows. Less information exists for summer-run steelhead as their smaller run size and higher altitude headwater holding areas have not been conducive for monitoring. Based on information from four streams, adult run time occur from mid-April to October with a higher concentration from July through September (NMFS 2005).

The majority of juveniles reside in the river system for two years with a minority migrating to the ocean as one or three-year olds. Smoltification and seaward migration occur from April to mid-May. The ocean growth period for Puget Sound steelhead ranges from one to three years in the ocean (Busby et al. 1996a). Juveniles or adults may spend considerable time in the protected marine environment of the fjord-like Puget Sound during migration to the high seas.

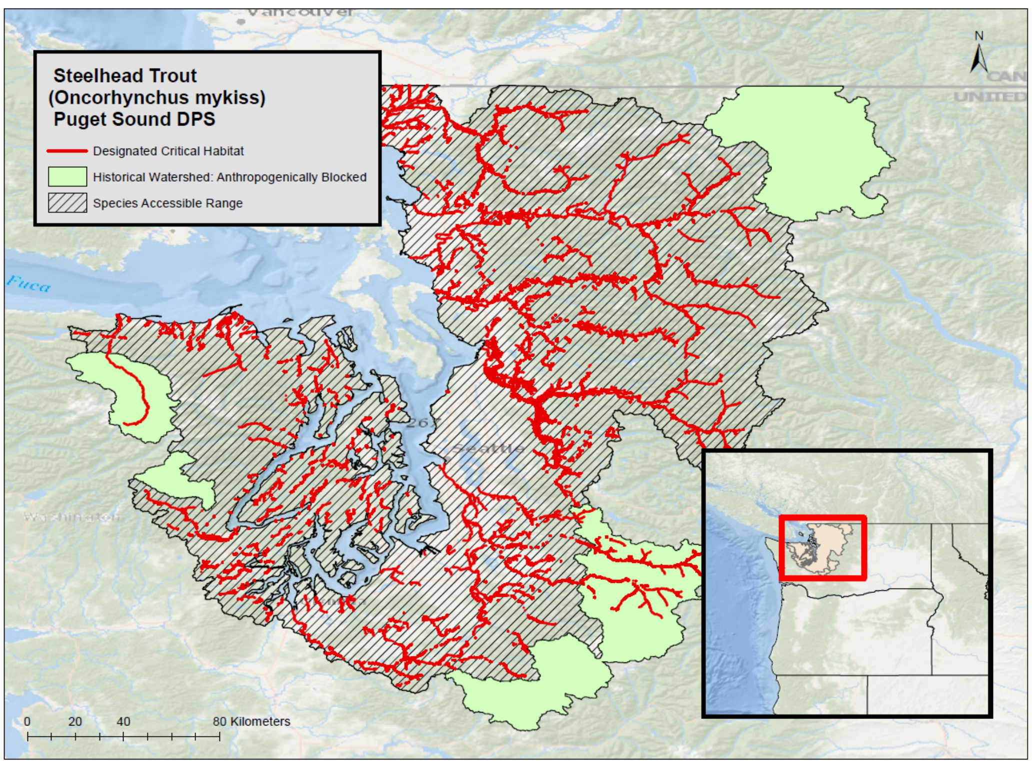

Figure 21. Geographic range and designated critical habitat of Puget Sound DPS steelhead.

8.18.2 Population Dynamics

Abundance of adult steelhead returning to nearly all Puget Sound rivers has fallen substantially since estimates began for many populations in the late 1970s and early 1980s. Inspection of geometric means of total spawner abundance from 2010 to 2014 indicates that nine of 20 populations evaluated had geometric mean abundances fewer than 250 adults and 12 of 20 had fewer than 500 adults.

Smoothed trends in abundance indicate modest increases since 2009 for 13 of the 22 DIPs. Between the two most recent five-year periods (2005 to 2009 and 2010 to 2014), the geometric mean of estimated abundance increased by an average of 5.4 percent. For seven populations in the Northern Cascades MPG, the increase was 3 percent; for five populations in the Central & South Puget Sound major MPG, the increase was 10 percent; and for six populations in the Hood Canal & Strait of Juan de Fuca MPG, the increase was 4.5 percent. However, several of these upward trends are not statistically different from neutral, and most populations remain small. Long-term (15-year) trends in natural spawners are predominantly negative NWFSC (2015a). Current abundance estimates for the Puget Sound DPS of steelhead trout are presented in Table 15 and Table 16 below.

Table 14. Expected 2019 Puget Sound steelhead listed hatchery releases (NMFS 2020).

Sub-basin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
Dungeness/Elwha	Dungeness	2018	Winter	10,000	-
	Hurd Creek	2018	Winter	-	34,500
Duwamish/Green	Flaming Geyser	2018	Winter	-	15,000
	Icy Creek	2018	Summer	50,000	-
			Winter	-	28,000
	Soos Creek	2018	Summer	50,000	-
Puyallup	White River	2018	Winter	-	35,000
Total Annual Release Number				110,000	112,500

Table 15. Abundance of Puget Sound steelhead spawner escapements (natural-origin and hatchery-production combined) from 2012-2016 (NMFS 2020).

Demographically Independent Populations	Spawners	Expected Number of Outmigrants
Central and South Puget Sound MPG		
Cedar River	3	391
Green River	977	111,179

Demographically Independent Populations	Spawners	Expected Number of Outmigrants
Nisqually River	759	86,323
N. Lake WA/Lake Sammamish	-	-
Puyallup/Carbon River	603	68,646
White River	629	71,638
Hood Canal and Strait of Juan de Fuca MPG		
Dungeness River[c]	26	2,984
East Hood Canal Tribs.	89	10,120
Elwha River	878	99,954
Sequim/Discovery Bay Tribs.	19	2,186
Skokomish River	862	98,066
South Hood Canal Tribs.	73	8,304
Strait of Juan de Fuca Tribs.	173	19,697
West Hood Canal Tribs.	122	13,858
North Cascades MPG		
Nooksack River	1,790	203,631
Pilchuck River	868	98,709
Samish River/ Bellingham Bay Tribs.	977	111,167
Skagit River	8,038	914,353
Snohomish/Skykomish Rivers	1,053	119,762
Snoqualmie River	824	93,772
Stillaguamish River	476	54,170
Tolt River	70	7,988
TOTAL	19,313	2,196,901

Only two hatchery stocks genetically represent native local populations (Hamma and Green River natural winter-run). The remaining programs, which account for the vast preponderance of production, are either out-of-DPS derived stocks or were within-DPS stocks that have diverged substantially from local populations. The WDFW estimated that 31 of the 53 stocks were of native origin and predominantly natural production (Washington Department of Fish and Wildlife (WDFW) 1993).

Fifty-three populations of steelhead have been identified in this DPS, of which 37 are winter-run. Summer-run populations are distributed throughout the DPS but are concentrated in northern Puget Sound and Hood Canal; only the Elwha River and Canyon Creek support summer-run steelhead in the rest of the DPS. The Elwha River run, however, is descended from introduced Skamania Hatchery summer-run steelhead. Historical summer-run steelhead in the Green River and Elwha River were likely extirpated in the early 1900s.

8.18.3 Status

For all but a few putative demographically independent populations of steelhead in Puget Sound, estimates of mean population growth rates obtained from observed spawner or redd counts are declining—typically three to 10 percent annually. Extinction risk within 100 years for most populations in the DPS is estimated to be moderate to high, especially for draft populations in the putative South Sound and Olympic MPGs. Collectively, these analyses indicate that steelhead in the Puget Sound DPS remain at risk of extinction throughout all or a significant portion of their range in the foreseeable future, but are not currently in danger of imminent extinction. The Biological Review for the latest 5-Year Review of the Puget Sound DPS of steelhead trout identified degradation and fragmentation of freshwater habitat, with consequent effects on connectivity, as the primary limiting factors and threats facing the Puget Sound steelhead DPS. The status of the listed Puget Sound steelhead DPS has not changed substantially since the 2007 listing. Most populations within the DPS are showing continued downward trends in estimated abundance, a few sharply so. The limited available information indicates that this DPS remains at a moderate risk of extinction.

8.18.4 Critical Habitat

NMFS designated critical habitat for Puget Sound steelhead on February 2, 2016 (81 FR 9251). The specific areas designated for Puget Sound steelhead include approximately 2,031 stream miles (3,269 kilometers) within the geographical area presently occupied by this DPS (Figure 22).

8.18.5 Recovery Goals

NMFS published a final recovery plan for the Puget Sound ESU of steelhead trout on December 20, 2019 (NMFS 2019b). The recovery plan's primary goals are as follows:

- The Puget Sound steelhead DPS achieves biological viability and the ecosystems upon which the DPS depends are conserved such that it is sustainable and persistent and no longer needs federal protection under the ESA; and
- The five listing factors from the ESA, section 4 (a)(1) are addressed. The five listing factors from the ESA, section 4(a)(1), include:

- The present or threatened destruction, modification, or curtailment of the species' habitat or range;
- Overutilization for commercial, recreational, scientific, or educational purposes;
- Disease or predation;
- Inadequacy of existing regulatory mechanisms; and
- Other natural or human-made factors affecting the species' continued existence.

Delisting criteria for the Puget Sound DPS of steelhead trout are detailed in NMFS (2019b).

8.19 Steelhead Trout – Snake River Basin DPS

The Snake River Basin DPS of steelhead trout includes naturally spawned steelhead originating below natural and manmade impassable barriers from the Snake River Basin (Figure 23), and also steelhead from six artificial propagation programs.

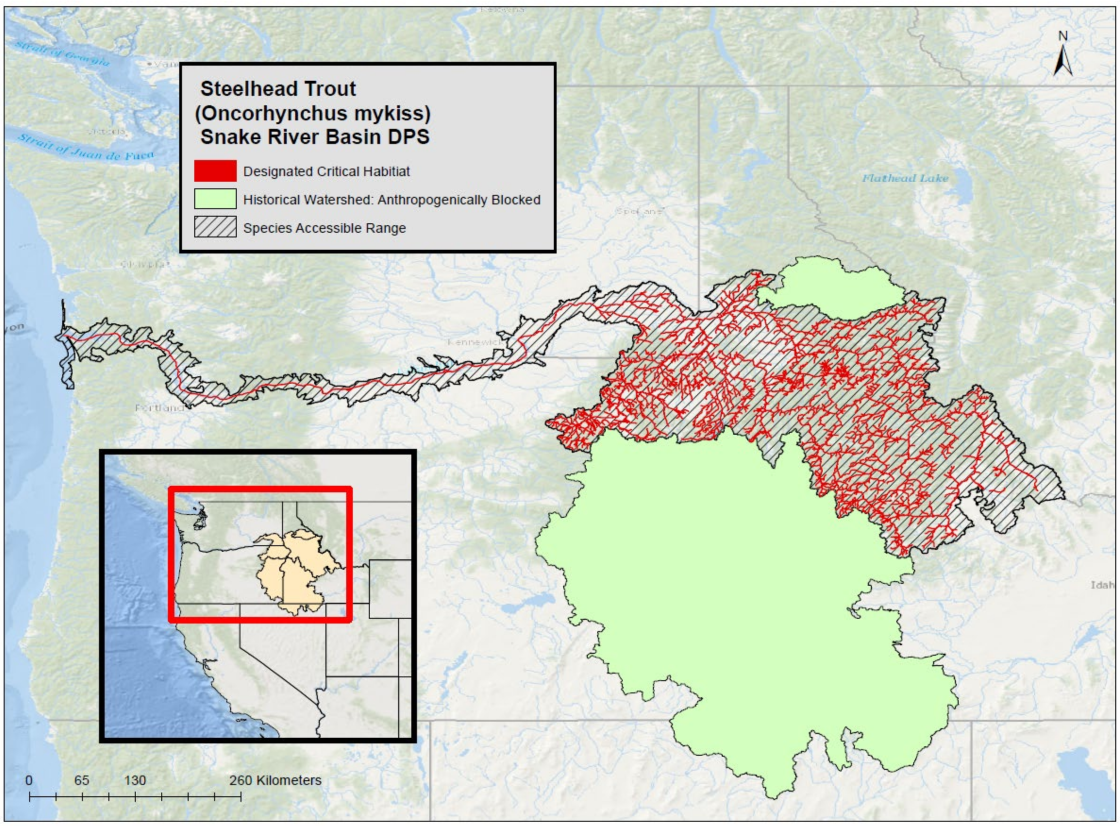

Figure 22. Geographic range and designated critical habitat of Snake River Basin steelhead.

On August 18, 1997 NMFS listed the Snake River Basin DPS of steelhead as threatened (62 FR 43937) and reaffirmed the DPS's status as threatened on January 5, 2006 (71 FR 834).

8.19.1 Life History

Snake River Basin steelhead are generally classified as summer-run fish. They enter the Columbia River from late June to October. After remaining in the river through the winter, Snake River Basin steelhead spawn the following spring (March to May). Managers recognize two life history patterns within this DPS primarily based on ocean age and adult size upon return: A-run or B-run. A-run steelhead are typically smaller, have a shorter freshwater and ocean residence (generally one year in the ocean), and begin their up-river migration earlier in the year. B-run steelhead are larger, spend more time in freshwater and the ocean (generally two years in ocean), and appear to start their upstream migration later in the year. Snake River Basin steelhead usually smolt after two or three years.

The life history for this DPS of steelhead trout is the same as that presented in Section 8.13.1.

8.19.2 Population Dynamics

There is uncertainty for wild populations of Snake River Basin DPS steelhead trout given limited data for adult spawners in individual populations. Regarding population growth rate, there are mixed long- and short-term trends in abundance and productivity. Overall, the abundances remain well below interim recovery criteria. Current abundance estimates for the Snake River Basin DPS of steelhead trout are presented in Table 17 below.

Table 16. Current Abundance Estimates for the Snake River Basin DPS of Steelhead Trout (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	10,547
Natural	Juvenile	798,341
Listed Hatchery Adipose Clipped	Adult	79,510
Listed Hatchery Adipose Clipped	Juvenile	3,300,152
Listed Hatchery Intact Adipose	Adult	16,137
Listed Hatchery Intact Adipose	Juvenile	705,490

8.19.3 Status

Four out of the five MPGs are not meeting the specific objectives in the draft recovery plan being written by NMFS based on the updated status information available for this review, and the status of many individual populations remains uncertain (NWFSC 2015b). The Grande Ronde MPG is tentatively rated as viable; more specific data on spawning abundance and the relative contribution of hatchery spawners for the Lower Grande Ronde and Wallowa populations would improve future assessments. A great deal of uncertainty still remains regarding the relative proportion of hatchery fish in natural spawning areas near major hatchery release sites within individual populations.

8.19.4 Critical Habitat

Critical habitat was designated for this species on September 2, 2005 (70 FR 52630). Critical habitat includes freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and estuarine areas.

8.19.5 Recovery Goals

NMFS published a final recovery plan for the Snake River Basin DPS of steelhead trout on November 30, 2017 (NMFS 2017d). The ESA recovery goal for Snake River Basin steelhead is that: The ecosystems upon which the steelhead depend are conserved such that the DPS is self-sustaining in the wild and no longer need ESA protection.

More information on the Snake River Basin DPS' recovery goals and delisting criteria are found in NMFS (2017d).

8.20 Steelhead Trout – South-Central California Coast DPS

The South-Central California Coast DPS of steelhead trout includes naturally spawned steelhead originating below natural and manmade impassable barriers from the Pajaro River to (but not including) the Santa Maria River. No artificially propagated steelhead populations that reside within the historical geographic range of this DPS are included in this designation. The two largest basins overlapping within the range of this DPS include the inland basins of the Pajaro River and the Salinas River (Figure 24).

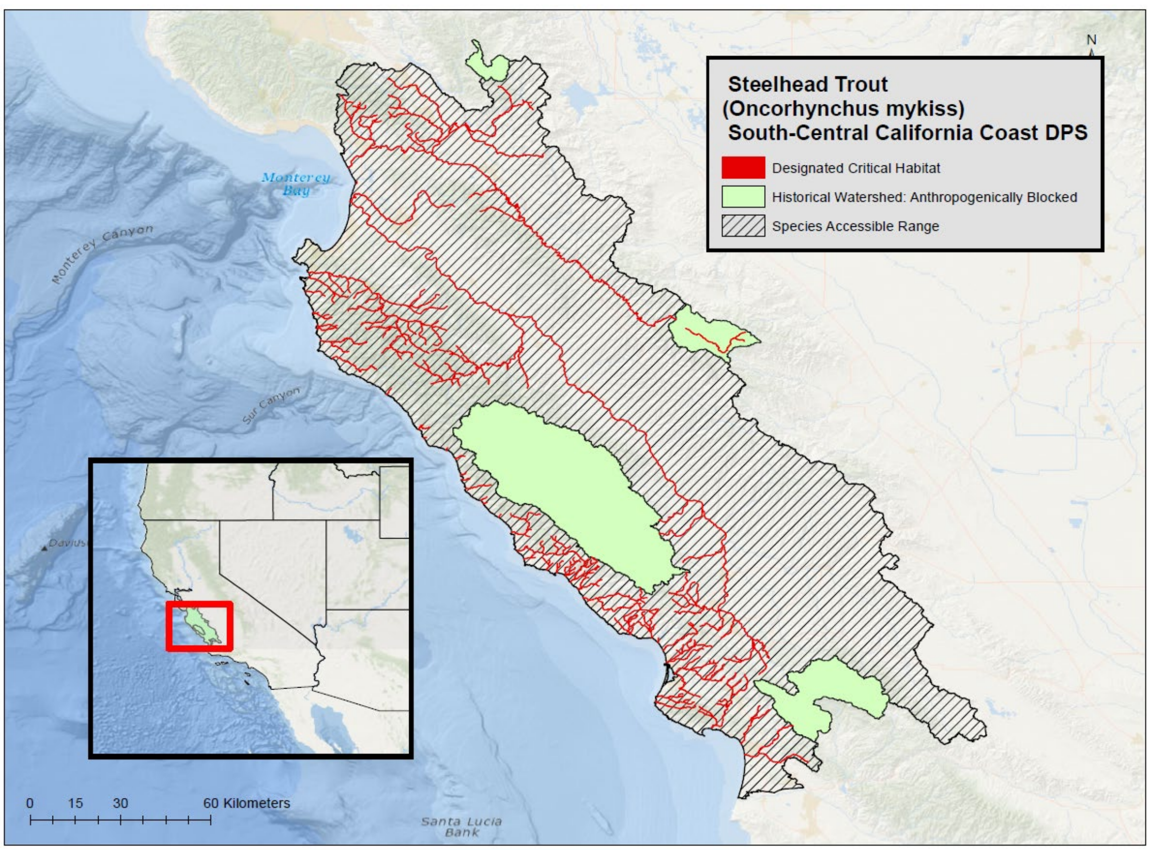

Figure 23. Geographic range and designated critical habitat of South-Central California Coast steelhead.

On August 18, 1997 NMFS listed the South-Central California Coast DPS of steelhead as threatened (62 FR 43937) and reaffirmed the DPS's status as threatened on January 5, 2006 (71 FR 5248).

8.20.1 Life History

There is limited life history information for steelhead in this DPS.

Only winter steelhead are found in the South-Central California Coast DPS of steelhead trout. Most spawning takes place from January through April. The life history for this DPS of steelhead trout is the same as that presented in Section 8.13.1.

8.20.2 Population Dynamics

The data summarized in the most recent status review indicate small (generally <10 fish) but surprisingly persistent annual runs of anadromous *O. mykiss* are currently being monitored across a limited but diverse set of basins within the range of this DPS, but interrupted in years when the mouth of the coastal estuaries fail to open to the ocean due to low flows (Williams et al. 2011). Current abundance estimates for the South-Central California Coast DPS of steelhead trout are presented in Table 18 below.

Table 17. Current Abundance Estimates for the South-Central California Coast DPS of Steelhead Trout (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	695
Natural	Juvenile	79,057

8.20.3 Status

Following the dramatic rise in South-Central California's human population after World War II and the associated land and water development within coastal drainages (particularly major dams and water diversions), steelhead abundance rapidly declined, leading to the extirpation of populations in many watersheds and leaving only sporadic and remnant populations in the remaining, more highly modified watersheds such as the Salinas River and Arroyo Grande Creek watersheds (NMFS 2013d). A substantial portion of the upper watersheds, which contain the majority of historical spawning and rearing habitats for anadromous *O. mykiss*, remain intact (though inaccessible to anadromous fish) and protected from intensive development as a result of their inclusion in the Los Padres National Forest (NMFS 2013d).

8.20.4 Critical Habitat

Critical habitat was designated for this species on September 2, 2005. Critical habitat includes freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and estuarine areas.

8.20.5 Recovery Goals

See the 2013 recovery plan for the South-Central California Coast steelhead DPS (NMFS 2013d) for complete down-listing/delisting criteria for recovery goals for the species. The recovery criteria are built upon having a viable population, one that has a negligible risk (less than five percent) of extinction due to demographic variation, natural environmental variation, and genetic diversity changes over a hundred year period, for the DPS as a whole and for each of the core populations within the recovery planning area.

8.21 Steelhead Trout – Upper Columbia River DPS

The Upper Columbia River DPS of steelhead trout includes naturally spawned anadromous steelhead originating below natural and manmade impassable barriers from the Columbia River and its tributaries upstream of the Yakima River to the U.S.-Canada border (Figure 25). Also, the Upper Columbia River DPS includes steelhead from six artificial propagation programs.

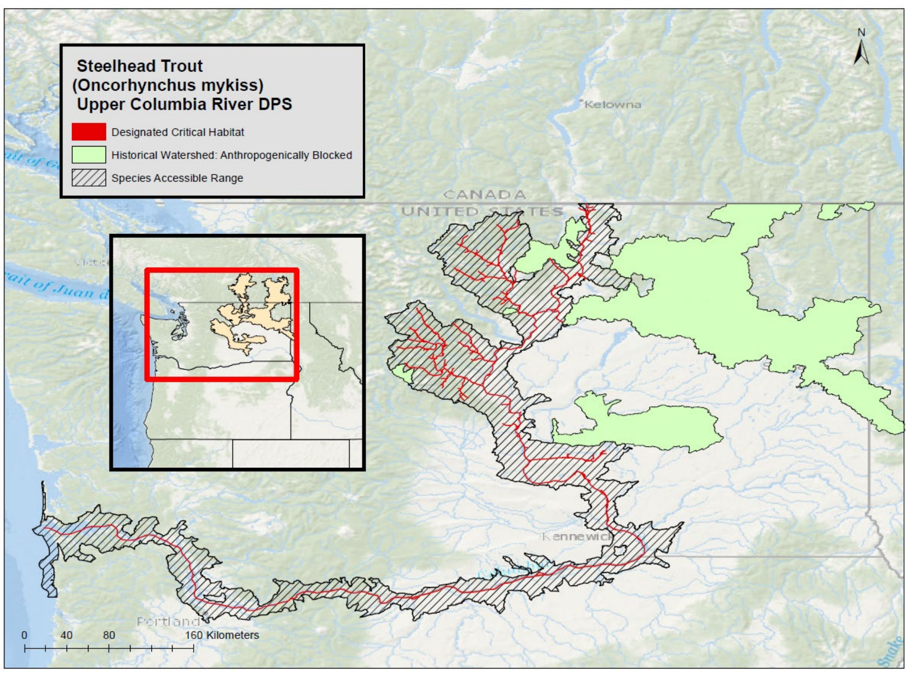

Figure 24. Geographic range and designated critical habitat of Upper Columbia River steelhead.

On August 18, 1997 NMFS listed the Upper Columbia River DPS of steelhead as endangered (62 FR 43937) and reaffirmed the DPS's status as endangered on January 5, 2006 (71 FR 834).

8.21.1 Life History

All Upper Columbia River steelhead are summer-run steelhead. Adults return in the late summer and early fall, with most migrating relatively quickly to their natal tributaries. A portion of the returning adult steelhead overwinter in mainstem reservoirs, passing over upper-mid-Columbia dams in April and May of the following year. Spawning occurs in the late spring of the year following river entry. Juvenile steelhead spend one to seven years rearing in freshwater before migrating to sea. Smolt out migrations are predominantly year class two and three (juveniles), although some of the oldest smolts are reported from this DPS at seven years. Most adult steelhead return to freshwater after one or two years at sea.

8.21.2 Population Dynamics

The most recent estimates of natural-origin spawner abundance for each of the four populations in the Upper Columbia River DPS of steelhead show fairly consistent patterns throughout the years. None of the populations has reached their recovery goal numbers during any of the years (500 for the Entiat, 2,300 for the Methow, 2,300 for the Okanogan, and 3,000 for Wenatchee). Current abundance estimates for the Upper Columbia River DPS of steelhead trout are presented in Table 19 below.

Table 18. Current Abundance Estimates for the Upper Columbia River DPS of Steelhead Trout (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	3,988
Natural	Juvenile	169,120
Listed Hatchery Adipose Clipped	Juvenile	662,848
Listed Hatchery Intact Adipose	Adult	2,403
Listed Hatchery Intact Adipose	Juvenile	144,067

Upper Columbia River steelhead populations have increased relative to the low levels observed in the 1990s, but natural origin abundance and productivity remain well below viability thresholds for three out of the four populations. In spite of recent increases, natural origin abundance and productivity remain well below viability thresholds for three out of the four populations, and the Okanogan River natural-origin spawner abundance estimates specifically are well below the recovery goal for that population. Three of four extant natural populations are considered to be at high risk of extinction and one at moderate risk.

All populations are at high risk for losing diversity, largely driven by chronic high levels of hatchery spawners within natural spawning areas and lack of genetic diversity among the populations.

The Upper Columbia River steelhead DPS is composed of three MPGs, two of which are isolated by dams. With the exception of the Okanogan population, the Upper Columbia River populations were rated as low risk for a loss of spatial structure (i.e., the physical process that drives diversity, as well as the features of a river system, and access to those features).

8.21.3 Status

Current estimates of natural origin spawner abundance increased relative to the levels observed in the prior review for all three extant populations, and productivities were higher for the Wenatchee and Entiat and unchanged for the Methow (NWFSC 2015b). However, abundance and productivity remained well below the viable thresholds called for in the Upper Columbia Recovery Plan for all three populations. Short-term patterns in those indicators appear to be largely driven by year-to year fluctuations in survival rates in areas outside of these watersheds. All three populations continued to be rated at low risk for spatial structure but at high risk for diversity criteria. Although the status of the ESU is improved relative to measures available at the time of listing, all three populations remain at high risk (NWFSC 2015b).

8.21.4 Critical Habitat

Critical habitat was designated for the Upper Columbia River DPS of steelhead trout on September 2, 2005 (70 FR 52630). Critical habitat includes freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and estuarine areas.

8.21.5 Recovery Goals

See the 2007 recovery plan for the Upper Columbia River steelhead DPS for complete down-listing/delisting criteria for recovery goals for the species (NMFS 2007b). Recovery plan goals involve addressing factors surrounding the abundance, productivity, spatial structure, and diversity of Upper Columbia River steelhead DPS related to hydropower, hatcheries, harvest, and habitat.

8.22 Steelhead Trout – Upper Willamette River DPS

This DPS includes naturally spawned anadromous winter-run *O. mykiss* (steelhead) originating below natural and manmade impassable barriers from the Willamette River and its tributaries upstream of Willamette Falls to and including the Calapooia River (Figure 26).

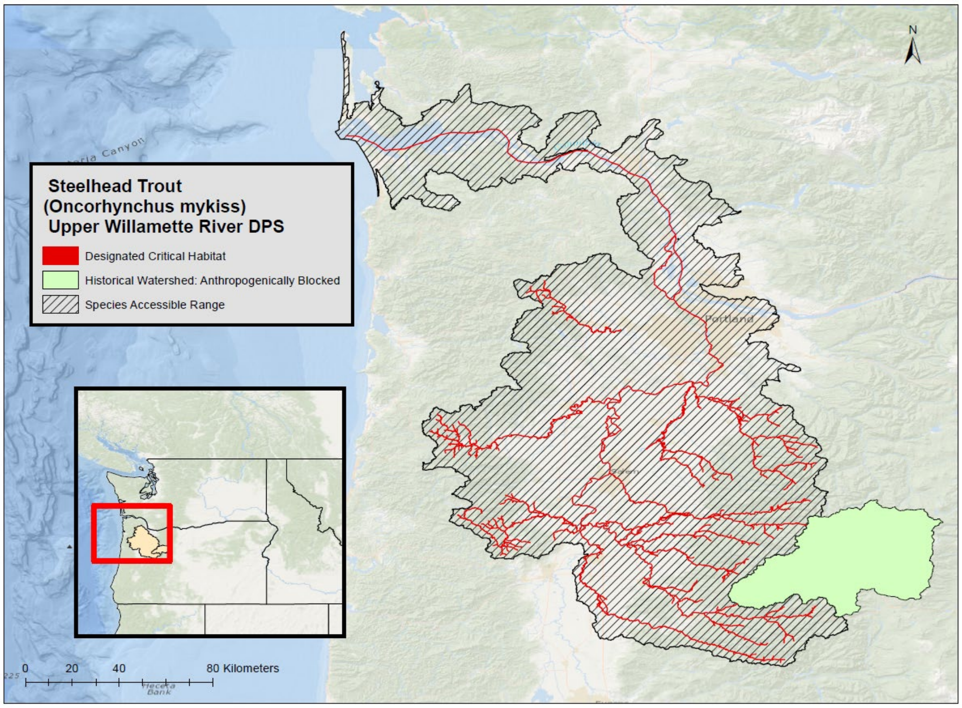

Figure 25. Geographic range and designated critical habitat of upper Willamette River steelhead.

On March 25, 1999 NMFS listed the Upper Willamette River DPS of steelhead as threatened (64 FR 14517) and reaffirmed the DPS's status as threatened on January 5, 2006 (71 FR 834).

8.22.1 Life History

Native steelhead in the Upper Willamette are a late-migrating winter group that enters freshwater in January and February (Howell et al. 1985). Upper Willamette River steelhead do not ascend to their spawning areas until late March or April, which is late compared to other West Coast winter steelhead. Spawning occurs from April to June 1. The unusual run timing may be an adaptation for ascending the Willamette Falls, which may have facilitated reproductive isolation of the stock. The smolt migration past Willamette Falls also begins in early April and proceeds into early June, peaking in early- to mid-May (Howell et al. 1985). Smolts generally migrate through the Columbia via Multnomah Channel rather than the mouth of the Willamette River. As with other coastal steelhead, the majority of juvenile smolts outmigrate after two years; adults return to their natal rivers to spawn after spending two years in the ocean. Repeat spawners are predominantly female and generally account for less than 10 percent of the total run size (Busby et al. 1996a).

8.22.2 Population Dynamics

For the Upper Willamette steelhead DPS, the declines in abundance noted during the previous status review continued through 2010 to 2015, and accessibility to historical spawning habitat remains limited, especially in the North Santiam River. Although the recent magnitude of these declines is relatively moderate, the NWFSC (NWFSC 2015b) notes that continued declines would be a cause for concern.

Recent estimates of escapement in the Molalla River indicate abundance is stable but at a depressed level, and the lack of migration barriers indicates this limitation is likely due to habitat degradation (NWFSC 2015b). In the North Santiam, radio-tagging studies and counts at Bennett Dam between 2010 and 2014 estimate the average abundance of returning winter-run adults is following a long-term negative trend (NWFSC 2015b). In the South Santiam live counts at Foster Dam indicate a negative trend in abundance from 2010 to 2014, and redd survey data indicate consistent low numbers of spawners in tributaries (NWFSC 2015b). Radio-tagging studies in the Calapooia from 2012 to 2014 suggest that abundances have been depressed but fairly stable, however long-term trends in redd counts conducted since 1985 are generally negative (NWFSC 2015b). Current abundance estimates for the Upper Willamette River DPS of steelhead trout are presented in Table 20 below.

Table 19. Current Abundance Estimates for the Upper Willamette River DPS of Steelhead Trout (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	2,912
Natural	Juvenile	143,898

Genetic analysis suggests that there is some level introgression among native late-winter steelhead and summer-run steelhead (Van Doornik et al. 2015), and up to approximately 10 percent of the juvenile steelhead at Willamette Falls and in the Santiam Basin may be hybrids (Johnson et al. 2013). While winter-run steelhead have largely maintained their genetic distinctiveness over time (Van Doornik et al. 2015), there are still concerns that hybridization will decrease the overall productivity of the native population. In addition, releases of large numbers of hatchery-origin summer steelhead may temporarily exceed rearing capacities and displace winter-run juvenile steelhead (NWFSC 2015b).

There are four demographically independent populations (DIPs) within the Upper Willamette River DPS of steelhead. Historical observations, hatchery records, and genetics suggest that the presence of Upper Willamette River DPS steelhead in many tributaries on the west side of the upper basin is the result of recent introductions. Nevertheless, the Willamette/Lower Columbia Technical Recovery Team recognized that although west side Upper Willamette River DPS steelhead does not represent a historical population, those tributaries may provide juvenile rearing habitat or may be temporarily (for one or more generations) colonized during periods of high abundance. Hatchery summer-run steelhead that are released in the subbasins are from an out-of-basin stock, and are not part of the DPS, nor are stocked summer steelhead that have become established in the McKenzie River (NMFS 2011h).

8.22.3 Status

Four basins on the east side of the Willamette River historically supported independent populations for the Upper Willamette River DPS steelhead, all of which remain extant. Data indicate that currently the two largest populations within the DPS are the Santiam River populations. Mean spawner abundance in both the North and South Santiam River is about 2,100 native winter-run steelhead. However, about 30 percent of all habitat has been lost due to human activities (McElhany et al. 2007). The North Santiam population has been substantially affected by the loss of access to the upper North Santiam basin. The South Santiam subbasin has lost habitat behind non-passable dams in the Quartzville Creek watershed. Notwithstanding the lost spawning habitat, the DPS continues to be spatially well distributed, occupying each of the four major subbasins.

Overall, the declines in abundance noted during the previous review continued through the period from 2010 to 2015 (NWFSC 2015b). There is considerable uncertainty in many of the abundance estimates, except for perhaps the tributary dam counts. Radio-tagging studies suggest that a considerable proportion of winter-run steelhead ascending Willamette Falls do not enter the DIPs that constitute this DPS; these fish may be nonnative early winter-run steelhead that appear to have colonized the western tributaries, misidentified summer-run steelhead, or late winter-run steelhead that have colonized tributaries not historically part of the DPS.

8.22.4 Critical Habitat

NMFS designated critical habitat for this species on September 2, 2005. Critical habitat includes freshwater spawning sites, freshwater rearing sites, freshwater migration corridors, and estuarine areas.

8.22.5 Recovery Goals

See the 2011 recovery plan for the Upper Willamette River steelhead DPS (NMFS 2011g) for complete down-listing/delisting criteria for recovery goals for the species. To qualify for delisting, the recovery plan recommends biologically based viability criteria, defined at the level of the DPS, strata (spatially related populations), and component populations. The viability criteria has five essential elements: stratified approach, the number of viable populations, the presence and status of representative populations, non-deterioration (i.e., all extant populations are maintained), and safety factors (i.e., buffering against risk of catastrophic events to ensure a population's viability).

8.23 Chinook Salmon – California Coastal ESU

The California Coastal Chinook salmon ESU includes all naturally spawned populations of Chinook salmon from rivers and streams south of the Klamath River (Humboldt County, CA) to the Russian River (Sonoma County, CA) (Figure 27).

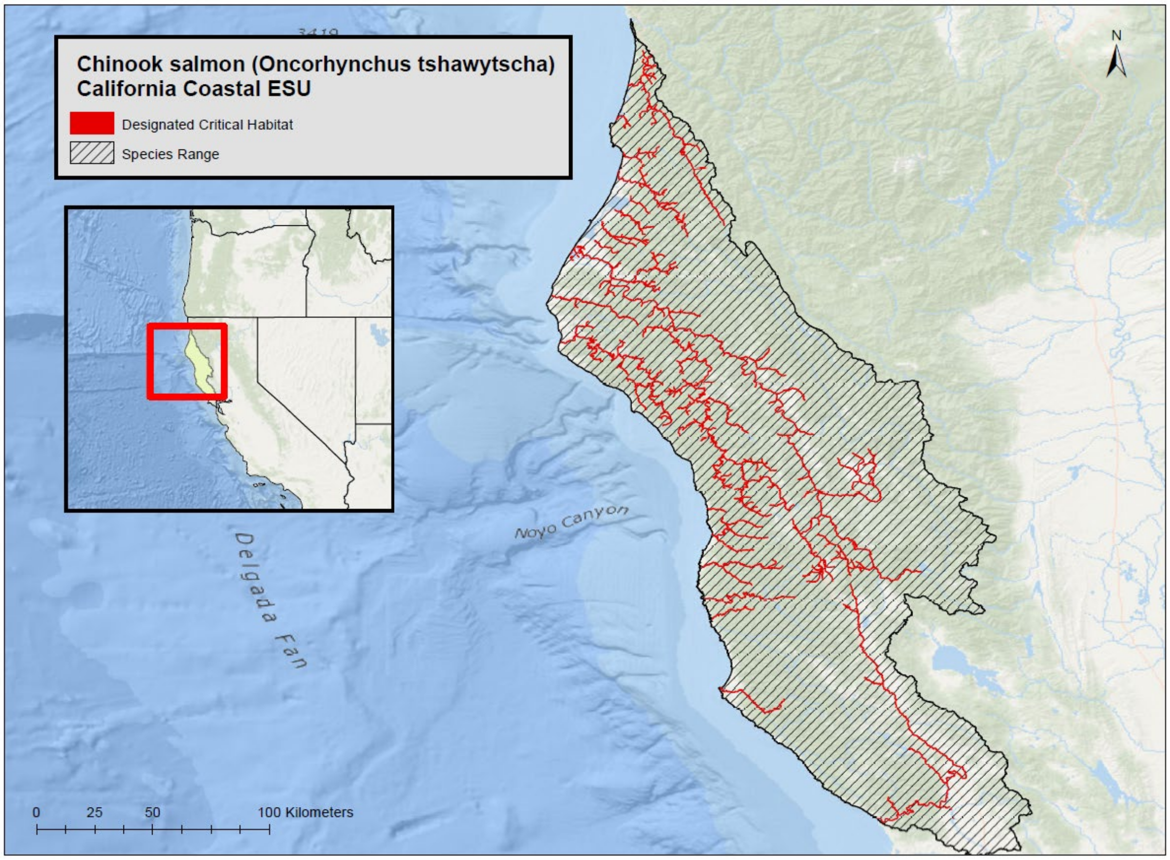

Figure 26. Geographic range and designated critical habitat of California coastal ESU Chinook salmon.

Chinook salmon, also referred to as king salmon in California, are the largest of the Pacific salmon. Spawning adults are olive to dark maroon in color, without conspicuous streaking or blotches on the sides. Spawning males are darker than females, and have a hooked jaw and slightly humped back. They can be distinguished from other spawning salmon by the color pattern, particularly the spotting on the back and tail, and by the dark, solid black gums of the lower jaw (Moyle 2002b). On September 16, 1999, NMFS listed the California Coastal ESU of Chinook salmon as a "threatened" species (FR 64 50394). On June 28, 2005, NMFS confirmed the listing of California Coastal Chinook salmon as threatened under the ESA and also added seven artificially propagated populations from the following hatcheries or programs to the listing.

8.23.1 Life History

California Coastal Chinook salmon are a fall-run, ocean-type fish. Although a spring-run (river-type) component existed historically, it is now considered extinct (Bjorkstedt et al. 2005). The different populations vary in run timing depending on latitude and hydrological differences between watersheds. Entry of California Coastal Chinook salmon into the Russian River depends on increased flow from fall storms, usually in November to January. Juveniles of this ESU migrate downstream from April through June and may reside in the estuary for an extended period before entering the ocean.

The length of time required for embryo incubation and emergence from the gravel is dependent on water temperature. For maximum embryo survival, water temperatures reportedly must be between 41°F and 55.4°F and oxygen saturation levels must be close to maximum. Under those conditions, embryos hatch in 40 to 60 days and remain in the gravel as alevins (the life stage between hatching and egg sack absorption) for another 4 to 6 weeks before emerging as fry. Juveniles may reside in freshwater for 12 to 16 months, but some migrate to the ocean as young-of-the-year in the winter or spring months within eight months of hatching.

Juvenile Chinook salmon forage in shallow areas with protective cover, such as tidally influenced sandy beaches and vegetated zones (Healey et al. 1991). Cladocerans, copepods, amphipods, and larvae of diptera, as well as small arachnids and ants are common prey items (Kjelson et al. 1982; MacFarlane and Norton 2002). Upon reaching the ocean, juvenile Chinook salmon feed voraciously on larval and juvenile fishes, plankton, and terrestrial insects (Healey et al. 1991; MacFarlane and Norton 2002). Chinook salmon grow rapidly in the ocean environment, with growth rates dependent on water temperatures and food availability.

8.23.2 Population Dynamics

Comparison of historical and current abundance information indicates that independent populations of Chinook salmon are depressed in many basins (Bennet 2005; Good et al. 2005; NMFS 2008a). Current abundance estimates for adult and juvenile California Coastal Chinook salmon are estimated to be 7,034 and 1,278,078 individuals, respectively (See Table 21).

Table 20. Average abundance for CC Chinook salmon natural-origin spawners (NMFS 2020).

Population	Years	Spawners	Expected Number of Outmigrants[ab]
Redwood Creek	2009-2013	1,745	317,067
Mad River	2010-2015	71	12,900
Freshwater Creek	2010-2015	6	1,090
Eel River mainstem	2010-2015	1,198	217,677
Eel River (Tomki Creek)	2010-2015	70	12,719
Eel River (Sproul Creek)	2010-2015	103	18,715
Mattole River	2007-2009, 2012, 2013	648	117,742

Population	Years	Spawners	Expected Number of Outmigrants[ab]
Russian River	2009 - 2014	3,137	569,993
Ten Mile River	2009 - 2014	6	1,090
Noyo River	2009 - 2014	14	2,544
Big River	2009 - 2014	13	2,362
Albion River	2009 - 2014	15	2,726
Navarro River	2009 - 2014	3	545
Garcia River	2009 - 2014	5	909
ESU Average		7,034	1,278,078

[a]Expected number of outmigrants=Total spawners*50 percent proportion of females*3,634 eggs per female*10 percent survival rate from egg to outmigrant.

[b]Based upon number of natural-origin spawners.

The available data, a mixture of short-term (6-year or less) population estimates or expanded red (nest) estimates and longer-term partial population estimates and spawner/red indexes, provide no indication that any of the independent populations (likely to persist in isolation) are approaching viability targets. Overall, there is a lack of compelling evidence to suggest that the status of these populations has improved or deteriorated appreciably since the previous status review (Williams et al. 2011).

At the ESU level, the loss of the spring-run life history type represents a significant loss of diversity within the ESU, as has been noted in previous status reviews (Williams et al. 2011). Concern remains about the extremely low numbers of Chinook salmon in most populations of the North-Central Coast and Central Coast strata, which diminishes connectivity across the ESU. However, the fact that Chinook salmon have regularly been reported in the Ten Mile, Noyo, Big, Navarro, and Garcia rivers represents a significant improvement in our understanding of the status of these populations in watersheds where they were thought to have been extirpated. These observations suggest that spatial gaps between extant populations are not as extensive as previously believed.

The California Coastal Chinook ESU includes all naturally spawned populations of Chinook salmon from rivers and streams south of the Klamath River to the Russian River, California (64 FR 50394; September 16, 1999). Seven artificial propagation programs are considered to be part of the ESU: The Humboldt Fish Action Council (Freshwater Creek), Yager Creek, Redwood Creek, Hollow Tree, Van Arsdale Fish Station, Mattole Salmon Group, and Mad River Hatchery fall-run Chinook hatchery programs. These artificially propagated stocks are no more divergent relative to the local natural population(s) than what would be expected between closely related natural populations within the ESU (NMFS 2016c).

8.23.3 Status

The California Coastal Chinook ESU was historically comprised of 38 populations which included 32 fall-run populations and 6 spring-run populations across four Diversity Strata (NWFSC 2015b). All six of the spring-run populations were classified as functionally independent, but are considered extinct (NMFS 2016c). NMFS (2016c) cited continued evidence of low population sizes relative to historical abundance, mixed trends in the few available time series of abundance indices available, and low abundance and extirpation of populations in the southern part of the ESU. In addition, the apparent loss of the spring-run life history type throughout the entire ESU as a significant diversity concern. The 2016 recovery plan determined that the four threats of greatest concern to the ESU are channel modification, roads and railroads, logging and wood harvesting, and both water diversion and impoundments and severe weather patterns.

8.23.4 Critical Habitat

NMFS designated critical habitat for the California Coastal Chinook salmon on September 2, 2005 (70 FR 52488). It includes multiple California watershed hydrological units north from Redwood Creek and south to Russian River.

8.23.5 Recovery Goals

Recovery goals, objectives and criteria for the California Coastal chinook salmon are fully outlined in NMFS (2016f). Recovery plan objectives are to:

- Reduce the present or threatened destruction, modification, or curtailment of habitat or range;
- Ameliorate utilization for commercial, recreational, scientific, or educational purposes;
- Abate disease and predation;
- Establish the adequacy of existing regulatory mechanisms for protecting California Coastal Chinook salmon now and into the future (i.e., post-delisting);
- Address other natural or manmade factors affecting the continued existence of California Coastal Chinook salmon; and
- Ensure the status of California Coastal Chinook salmon is at a low risk of extinction based on abundance, growth rate, spatial structure and diversity.

8.24 Chinook Salmon – Central Valley Spring-Run ESU

The Chinook salmon, Central Valley spring-run ESU includes naturally spawned spring-run Chinook salmon originating from the Sacramento River and its tributaries, and also spring-run Chinook salmon from the Feather River Hatchery Spring-run Chinook Program (Figure 30).

On September 16, 1999, NMFS listed the Central Valley ESU of spring-run Chinook salmon as a "threatened" species (FR 64 50394). Historically, spring-run Chinook salmon occurred in the headwaters of all major river systems in the Central Valley where natural barriers to migration were absent. The only known streams that currently support self-sustaining populations of nonhybridized spring-run Chinook salmon in the Central Valley are Mill, Deer and Butte creeks. Each of these populations is small and isolated (NMFS 2014b).

8.24.1 Life History

Adult Central Valley spring-run Chinook salmon leave the ocean to begin their upstream migration in late January and early February, and enter the Sacramento River between March and September, primarily in May and June (Yoshiyama et al. 1998; Moyle 2002b). Spring-run Chinook salmon generally enter rivers as sexually immature fish and must hold in freshwater for up to several months before spawning. While maturing, adults hold in deep pools with cold water. Spawning normally occurs between mid- August and early October, peaking in September (Moyle 2002b).

The life history for this ESU of Chinook salmon is the same as presented in Section 8.23.1.

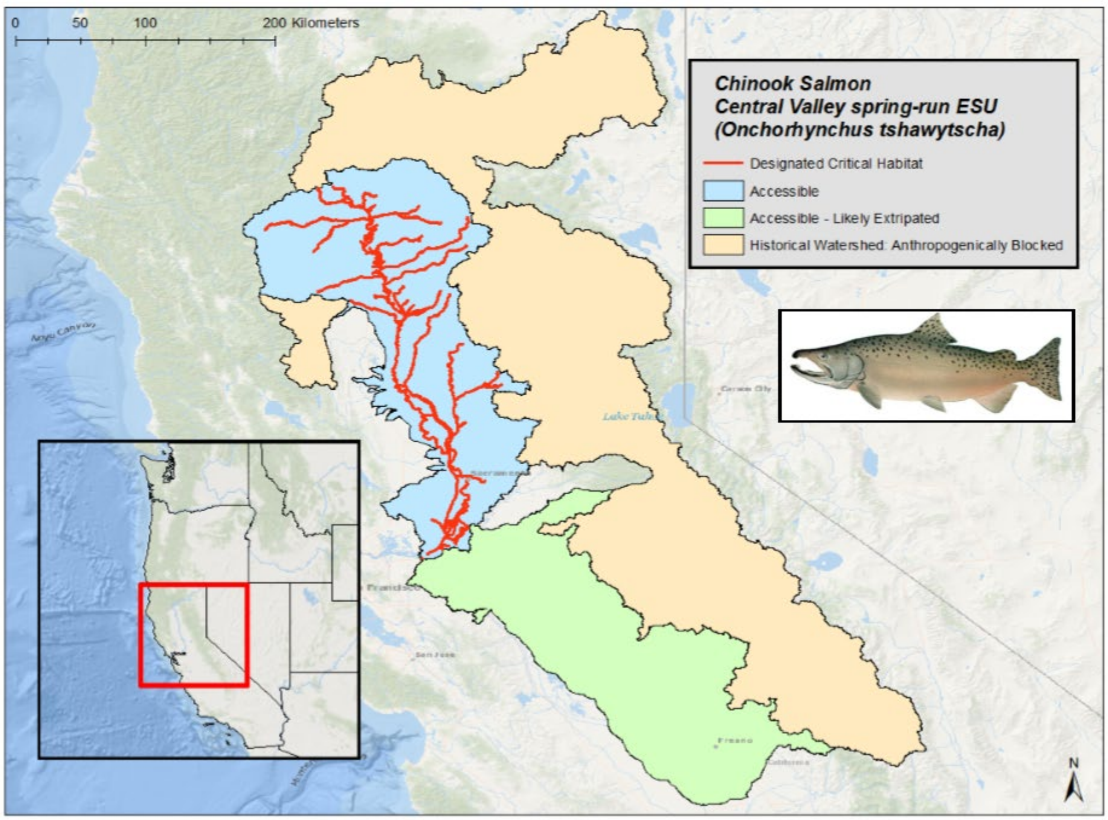

Figure 27. Geographic range and designated critical habitat of Central Valley spring-run ESU Chinook salmon.

8.24.2 Population Dynamics

The Central Valley as a whole is estimated to have supported spring-run Chinook salmon runs as large as 600,000 fish between the late 1880s and 1940s. Current abundance estimates for the Central Valley spring-run ESU of Chinook salmon are presented in Table 22 below.

Table 21. Average abundance estimates for Central Valley Spring Run Chinook salmon natural- and hatchery-origin spawners from 2013 to 2017 (NMFS 2020).

Population Name	Natural-origin Spawners[a]	Hatchery-origin Spawners[a]	% Hatchery Origin	Expected Number of Outmigrants[b]
Southern Cascades Stratum				
Battle Creek	191	0	0%	39,761
Mill Creek	302	0	0%	62,807
Deer Creek	409	0	0%	85,049
Butte Creek	2,750	0	0%	572,056
Big Chico Creek	0	0	0%	0
Antelope Creek	3	0	0%	598
Coastal Range Stratum				
Clear Creek	73	0	0%	15,143
Cottonwood / Beegum creeks	0.3	0	0%	60
Northern Sierra Stratum				
Feather River	0	2,273	100%	-
ESU Average	3,727	2,273	37.9%	775,474

[a] Geometric mean (2013-2017) of post-fishery spawners.

[b]Based upon number of natural-origin spawners.

Cohort replacement rates (CRR) are indications of whether a cohort is replacing itself in the next generation. The majority of Central Valley spring-run Chinook salmon are found to return as three-year olds, therefore looking at returns every three years is used as an estimate of the CRR. In the past, the CRR has fluctuated between just over 1.0 to just under 0.5, and in the recent years with high returns (2012 and 2013), CRR jumped to 3.84 and 8.68 respectively. CRR for 2014 was 1.85, and the CRR for 2015 with very low returns was a record low of 0.14. Low returns in 2015 were further decreased due to high temperatures and most of the Central Valley spring-run Chinook salmon tributaries experienced some pre-spawn mortality. Butte Creek experienced the highest prespawn mortality in 2015, resulting in a carcass survey CRR of only 0.02.

Threats to the genetic integrity of spring-run Chinook salmon was identified as a serious concern to the species when it was listed in 1999 (Myers et al. 1998a; FR 64 50394). Three main factors compromised the genetic integrity of spring-run Chinook salmon: (1) the lack of reproductive isolation following dam construction throughout the Central Valley resulting in introgression with fall-run Chinook salmon in the wild; (2) within basin and inter-basin mixing between spring and fall broodstock for artificial propagation, resulting in introgression in hatcheries; and (3) releasing hatchery-produced juvenile Chinook salmon in the San Francisco estuary, which contributes to the straying of returning adults throughout the Central Valley (NMFS 2014b).

The Central Valley Technical Recovery Team delineated 18 or 19 historic independent populations of Central Valley spring-run Chinook salmon, and a number of smaller dependent populations, that are distributed among four diversity groups (southern Cascades, northern Sierra, southern Sierra, and Coast Range) (Lindley et al. 2004). Of these independent populations, only three are extant (Mill, Deer, and Butte creeks) and they represent only the northern Sierra Nevada diversity group. Of the dependent populations, Central Valley spring-run Chinook salmon are found in Battle, Clear, Cottonwood, Antelope, Big Chico, and Yuba creeks, as well as the Sacramento and Feather rivers and a number of tributaries of the San Joaquin River including Mokelumne, Stanislaus, and Tuolumne rivers. The 2005 listing determination concluded that the Feather River Fish Hatchery spring-run Chinook salmon production should be included in the Central Valley spring-run Chinook salmon ESU (NWFSC 2015b).

8.24.3 Status

Although spring-run Chinook salmon were probably the most abundant salmonid in the Central Valley, this ESU has suffered the most severe declines of any of the four Chinook salmon runs in the Sacramento River Basin (Fisher 1994). The ESU is currently limited to independent populations in Mill, Deer, and Butte Creeks, persistent and presumably dependent populations in the Feather and Yuba rivers and in Big Chico, Antelope, and Battle Creeks, and a few ephemeral or dependent populations in the Northwestern California region (e.g., Beegum, Clear, and Thomes Creeks). The Central Valley spring-run Chinook salmon ESU is currently faced with three primary threats: (1) loss of most historic spawning habitat; (2) degradation of the remaining habitat; and (3) genetic introgression with the Feather River fish hatchery spring-run Chinook salmon strays. The potential effects of climate change are likely to adversely affect spring-run Chinook salmon and their recovery (NMFS 2014b).

8.24.4 Critical Habitat

NMFS published a final rule designating critical habitat for Central Valley spring-run Chinook on September 2, 2005 (70 FR 52488).

8.24.5 Recovery Goals

Recovery goals, objectives and criteria for the Central Valley spring-run Chinook are fully outlined in the 2014 Recovery Plan (NMFS 2014b). The ESU delisting criteria for the spring-run Chinook are:

- One population in the Northwestern California Diversity Group at low risk of extinction;
- Two populations in the Basalt and Porous Lava Diversity Group at low risk of extinction;
- Four populations in the Northern Sierra Diversity Group at low risk of extinction;
- Two populations in the Southern Sierra Diversity Group at low risk of extinction; and
- Maintain multiple populations at moderate risk of extinction.

8.25 Chinook Salmon – Lower Columbia River ESU

Chinook salmon, Lower Columbia River ESU includes naturally spawned Chinook salmon originating from the Columbia River and its tributaries downstream of a transitional point east of the Hood and White Salmon Rivers, and any such fish originating from the Willamette River and its tributaries below Willamette Falls (Figure 29).

On March 24, 1999, NMFS listed the Lower Columbia River ESU of Chinook salmon as a "threatened" species (64 FR 14308). The listing was revisited and confirmed as "threatened" in 2005 (70 FR 37160).

8.25.1 Life History

Lower Columbia River Chinook salmon display three run types including early fall-runs, late fall-runs, and spring-runs. Presently, the fall-run is the predominant life history type. Spring-run Chinook salmon were numerous historically. Fall-run Chinook salmon enter freshwater typically in August through October. Early fall-run spawn within a few weeks in large river mainstems. The late fall-run enters in immature conditions, has a delayed entry to spawning grounds, and resides in the river for a longer time between river entry and spawning. Spring-run Chinook salmon enter freshwater in March through June to spawn in upstream tributaries in August and September.

Offspring of fall-run spawning may migrate as fry to the ocean soon after yolk absorption (i.e., ocean-type), at 30 to 45 millimeters in length (Healey 1991). In the Lower Columbia River system, however, the majority of fall-run Chinook salmon fry migrate either at 60 to 150 days post-hatching in the late summer or autumn of their first year. Offspring of fall-run spawning may also include a third group of yearling juveniles that remain in freshwater for their entire first year before emigrating. The spring-run Chinook salmon migrates to the sea as yearlings

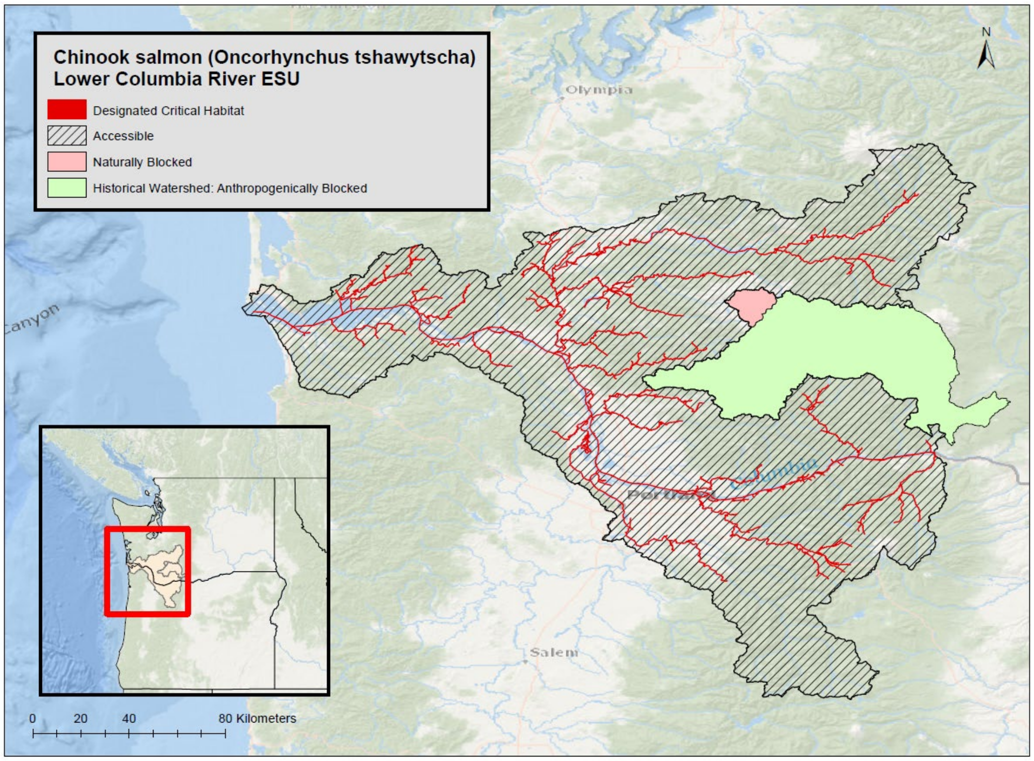

Figure 28. Geographic range and designated critical habitat of Lower Columbia River ESU Chinook salmon.

(stream-type) typically in spring. However, the natural timing of Lower Columbia River spring-run Chinook salmon emigration is obscured by hatchery releases (Myers et al. 2006). Once at sea, the ocean-type Columbia River Chinook salmon tend to migrate along the coast, while stream-type Lower Columbia River Chinook salmon appear to move far off the coast into the central North Pacific Ocean (Healey 1991; Myers et al. 2006). Adults return to tributaries in the Lower Columbia River predominately as three- and four-year-olds for fall-run fish and four- and five-year-olds for spring-run fish.

The life history for this ESU of Chinook salmon is the same as presented in Section 8.23.1.

8.25.2 Population Dynamics

Populations of Lower Columbia River Chinook salmon have declined substantially from historical levels. Many of the ESU's populations are believed to have very low abundance of natural-origin spawners (100 fish or fewer), which increases genetic and demographic risks. Other populations have higher total abundance, but several of these also have high proportions of hatchery-origin spawners. Current abundance estimates for the Lower Columbia River ESU of Chinook salmon are presented in Table 23 below.

Table 22. Abundance Estimates for the Lower Columbia River ESU of Chinook Salmon (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	29,469
Natural	Juvenile	11,745,027
Listed Hatchery Intact Adipose	Juvenile	962,458
Listed Hatchery Clipped and Intact Adipose	Adult	38,594
Listed Hatchery Adipose Clip	Juvenile	31,353,395

The genetic diversity of all populations (except the late fall-run Chinook salmon) has been eroded by large hatchery influences and periodically by low effective population sizes. The near loss of the spring-run life history type remains an important concern for maintaining diversity within the ESU.

The ESU spans three distinct ecological regions: Coastal, Cascade, and Gorge. Distinct life-histories (run and spawn timing) within ecological regions in this ESU were identified as MPGs. In total, 32 historical demographically independent populations (DIPs) were identified in this ESU, 9 spring-run, 21 fall-run, and 2 late-fall run, organized in 6 MPGs (based on run timing and ecological region). The basin-wide spatial structure has remained generally intact. However, the loss of about 35 percent of historic habitat has affected distribution within several Columbia River subbasins.

8.25.3 Status

Populations of Lower Columbia River Chinook salmon have declined substantially from historical levels. Out of the 32 populations that make up this ESU, only the two late-fall runs (the North Fork Lewis and Sandy) are considered viable. Most populations (26 out of 32) have a very low probability of persistence over the next 100 years and some are extirpated or nearly so. Five of the six strata fall significantly short of the recovery plan criteria for viability. Low abundance, poor productivity, losses of spatial structure, and reduced diversity all contribute to the very low persistence probability for most Lower Columbia River Chinook salmon populations. Hatchery contribution to naturally spawning fish remains high for a number of populations, and it is likely that many returning unmarked adults are the progeny of hatchery origin parents, especially where large hatchery programs operate. Continued land development and habitat degradation in combination with the potential effects of climate change will present a continuing strong negative influence into the foreseeable future.

8.25.4 Critical Habitat

NMFS designated critical habitat for Lower Columbia River Chinook salmon on September 2, 2005 (70 FR 52630). It includes all Columbia River estuarine areas and river reaches proceeding upstream to the confluence with the Hood Rivers, as well as specific stream reaches in a number of tributary subbasins.

8.25.5 Recovery Goals

Recovery plan targets for this species are tailored for each life history type, and within each type, specific population targets are identified (NMFS 2013b). For spring Chinook salmon, all populations are affected by aspects of habitat loss and degradation. Four of the nine populations require significant reductions in every threat category. Protection and improvement of tributary and estuarine habitat are specifically noted.

For fall Chinook salmon, recovery requires restoration of the Coast and Cascade strata to high probability of persistence, to be achieved primarily by ensuring habitat protection and restoration. Very large improvements are needed for most fall Chinook salmon populations to improve their probability of persistence.

For late fall Chinook salmon, recovery requires maintenance of the North Fork Lewis and Sandy populations which are comparatively healthy, together with improving the probability of persistence of the Sandy population from its current status of "high" to "very high." Improving the status of the Sandy population depends largely on harvest and hatchery changes. Habitat improvements to the Columbia River estuary and tributary spawning areas are also necessary. Of the 32 DIPs in this ESU, only the two late-fall run populations (Lewis River and Sandy River) could be considered viable or nearly so (NWFSC 2015b).

8.26 Chinook Salmon – Puget Sound ESU

The Puget Sound ESU includes naturally spawned Chinook salmon originating from rivers flowing into Puget Sound from the Elwha River (inclusive) eastward, including rivers in Hood Canal, South Sound, North Sound and the Georgia Strait. Twenty-six artificial propagation programs are included as part of the Puget Sound ESU (Figure 32).

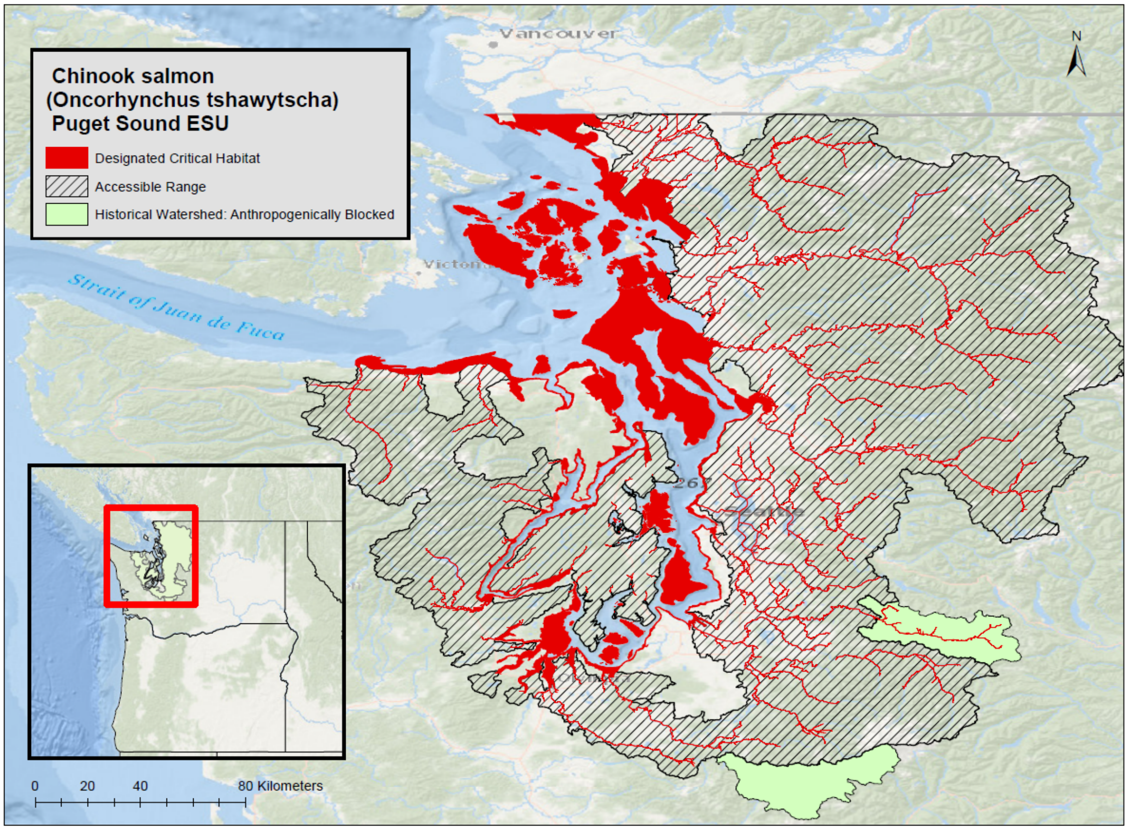

Figure 29. Geographic range and designated critical habitat of Puget Sound ESU Chinook salmon.

On March 24, 1999, NMFS listed the Puget Sound ESU of Chinook salmon as a "threatened" species (64 FR 14308). The listing was revisited and confirmed as "threatened" in 2005 (70 FR 37160).

8.26.1 Life History

Puget Sound Chinook salmon populations are both early-returning (August) and late-returning (mid-September and October) spawners (Healey 1991). Juvenile Chinook salmon within the Puget Sound generally exhibit an "ocean-type" life history. However, substantial variation occurs with regard to juvenile residence time in freshwater versus estuarine environments. Hayman (Hayman et al. 1996) described three juvenile life histories for Chinook salmon with varying freshwater and estuarine residency times in the Skagit River system in northern Puget Sound. In this system, 20 percent to 60 percent of sub-yearling migrants rear for several months in freshwater habitats while the remaining fry migrate to rear in the Skagit River estuary and delta (Beamer et al. 2005). Juveniles in tributaries to Lake Washington exhibit both a stream rearing and a lake rearing strategy. Lake rearing fry are found in highest densities in nearshore shallow (<1 meter) habitat adjacent to the opening of tributaries or at the mouth of tributaries where they empty into the lake (Tabor et al. 2006). Puget Sound Chinook salmon also have several estuarine rearing juvenile life history types that are highly dependent on estuarine areas for rearing (Beamer et al. 2005). In the estuaries, fry use tidal marshes and connected tidal channels including dikes and ditches developed to protect and drain agricultural land. During their first ocean year, immature Chinook salmon use nearshore areas of Puget Sound during all seasons and can be found long distances from their natal river systems (Brennan et al. 2004).

The life history for this ESU of Chinook salmon is the same as presented in Section 8.23.1.

8.26.2 Population Dynamics

Estimates of the historic abundance range from 1,700 to 51,000 potential Puget Sound Chinook salmon spawners per population. During the period from 1996 to 2001, the geometric mean of natural spawners in populations of Puget Sound Chinook salmon ranged from 222 to just over 9,489 fish. Thus, the historical estimates of spawner capacity are several orders of magnitude higher than spawner abundances currently observed throughout the ESU (Good et al. 2005). Current abundance estimates for the Puget Sound ESU of Chinook salmon are found in Table 24 and Table 25 below.

Table 23. Average abundance estimates for Puget Sound Chinook salmon natural- and hatchery-origin spawners 2012-2016 (NMFS 2020).

Population Name	Natural-origin Spawners[a]	Hatchery-origin Spawners[a]	% Hatchery Origin	Minimum Viability Abundance[b]	Expected Number of Outmigrants[c]
Georgia Strait MPG					
NF Nooksack River[d]	181	945	83.95%	16,000	90,009
SF Nooksack River[d]	18	15	45.04%	9,100	2,597
Strait of Juan de Fuca MPG					
Elwha River	130	2,156	94.30%	15,100	182,895
Dungeness River	189	213	52.91%	4,700	32,163
Hood Canal MPG					
Skokomish River	224	1,158	83.82%	12,800	110,505
Mid-Hood Canal	165	117	41.55%	11,000	22,589
Whidbey Basin MPG					
Skykomish River	2,001	1,466	42.29%	17,000	277,348
Snoqualmie River	881	219	19.93%	17,000	87,978
NF Stillaguamish River	385	291	43.04%	17,000	54,137

Population Name	Natural-origin Spawners[a]	Hatchery-origin Spawners[a]	% Hatchery Origin	Minimum Viability Abundance[b]	Expected Number of Outmigrants[c]
SF Stillaguamish River	42	29	40.57%	15,000	5,676
Upper Skagit River	9,505	120	1.25%	17,000	770,047
Lower Skagit River	2,207	13	0.60%	16,000	177,643
Upper Sauk River	1,106	5	0.46%	3,000	88,899
Lower Sauk River	559	3	0.59%	5,600	44,984
Suiattle River	590	5	0.77%	600	47,582
Cascade River	205	7	3.12%	1,200	16,937
Central / South Sound MPG					
Sammamish River	125	885	87.64%	10,500	80,823
Cedar River	883	440	33.26%	11,500	105,864
Duwamish/Green River	1,120	4,171	78.83%	17,000	423,326
Puyallup River	565	1,240	68.72%	17,000	144,384
White River	569	1,438	71.64%	14,200	160,622
Nisqually River	747	606	44.81%	13,000	108,281
ESU Average	22,398	15,543	40.97%		3,035,288

a Five-year geometric mean of post-fishery spawners (2013-2017).

b Ford 2011

c Expected number of outmigrants=Total spawners*40% proportion of females*2,000 eggs per female*10% survival rate from egg to outmigrant

d 2012-2016 five year geometric mean (2017 data not available).

Table 24. Expected 2019 Puget Sound Chinook salmon hatchery releases (NMFS 2020).

Sub-basin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
Deschutes	Tumwater Falls	2018	Fall	3,800,000	-

Sub-basin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
Dungeness-Elwha	Dungeness	2018	Spring	-	50,000
	Elwha	2017	Fall	-	200,000
		2018	Fall	250,000	2,250,000
	Gray Wolf River	2018	Spring	-	50,000
	Hurd Creek	2018	Spring	-	50,000
	Upper Dungeness Pond	2018	Spring	-	50,000
Duwamish	Icy Creek	2017	Fall	300,000	-
	Palmer	2018	Fall	-	1,000,000
	Soos Creek	2018	Fall	3,000,000	200,000
Hood Canal	Hood Canal Schools	2018	Fall	-	500
	Hoodsport	2017	Fall	120,000	-
		2018	Fall	3,000,000	-
Kitsap	Bernie Gobin	2017	Spring	40,000	-
		2018	Fall	-	200,000
			Summer	2,300,000	100,000
	Garrison	2018	Fall	850,000	-
	George Adams	2018	Fall	3,375,000	425,000
	Gorst Creek	2018	Fall	730,000	-
	Grovers Creek	2018	Fall	1,250,000	-
	Hupp Springs	2018	Spring	-	400,000
	Lummi Sea Ponds	2018	Fall	500,000	-
	Minter Creek	2018	Fall	1,250,000	-
Lake Washington	Salmon in the Schools	2018	Fall	-	540
	Issaquah	2018	Fall	2,000,000	-
Nisqually	Clear Creek	2018	Fall	3,300,000	200,000

Sub-basin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
	Kalama Creek	2018	Fall	600,000	-
	Nisqually MS	2018	Fall	-	90
Nooksack	Kendall Creek	2018	Spring	800,000	-
	Skookum Creek	2018	Spring	-	1,000,000
Puyallup	Clarks Creek	2018	Fall	400,000	-
	Voights Creek	2018	Fall	1,600,000	-
	White River	2017	Spring	-	55,000
		2018	Spring	-	340,000
San Juan Islands	Glenwood Springs	2018	Fall	725,000	-
Skokomish	McKernan	2018	Fall	-	100,000
Skykomish	Wallace River	2017	Summer	500,000	-
		2018	Summer	800,000	200,000
Stillaguamish	Brenner	2018	Fall	-	200,000
	Whitehorse Pond	2018	Summer	220,000	-
Georgia Strait	Samish	2018	Fall	3,800,000	200,000
Upper Skagit	Marblemount	2018	Spring	387,500	200,000
			Summer	200,000	-
Total Annual Release Number				36,297,500	7,271,130

Available data on total abundance since 1980 indicate that although abundance trends have fluctuated between positive and negative for individual populations, there are widespread negative trends in natural-origin Chinook salmon spawner abundance across the ESU (Ford 2011a). Productivity remains low in most populations, and hatchery-origin spawners are present in high fractions in most populations outside of the Skagit watershed. Available data now shows that most populations have declined in abundance over the past 7 to 10 years. Further, escapement levels for all populations remain well below the Technical Recovery Team planning ranges for recovery, and most populations are consistently below the spawner-recruit levels identified by the Technical Recovery Team as consistent with recovery (Ford 2011a).

Current estimates of diversity show a decline over the past 25 years, indicating a decline of salmon in some areas and increases in others. Salmon returns to the Whidbey Region increased in abundance while returns to other regions declined. In aggregate, the diversity of the ESU as a whole has been declining over the last 25 years.

The Puget Sound technical recovery team identified 22 extant populations, grouped into five major geographic regions, based on consideration of historical distribution, geographic isolation, dispersal rates, genetic data, life history information, population dynamics, and environmental and ecological diversity.

8.26.3 Status

All Puget Sound Chinook salmon populations are well below escapement abundance levels identified as required for recovery to low extinction risk in the recovery plan. In addition, most populations are consistently below the productivity goals identified in the recovery plan as necessary for recovery. Although trends vary for individual populations across the ESU, most populations have declined in total natural origin recruit abundance since the last status review; and natural origin recruit escapement trends since 1995 are mostly stable. Several of the risk factors identified in the previous status review (Good et al. 2005) are still present, including high fractions of hatchery fish in many populations and widespread loss and degradation of habitat. Although this ESU's total abundance is a greatly reduced from historic levels, recent abundance levels do not indicate that the ESU is at immediate risk of extinction. This ESU remains relatively well distributed over 22 populations in five geographic areas across the Puget Sound. Although current trends are concerning, the available information indicates that this ESU remains at moderate risk of extinction (NMFS 2011a).

8.26.4 Critical Habitat

Critical habitat was designated for the Puget Sound ESU of Chinook salmon on September 2, 2005 (70 FR 52630) and includes 1,683 miles of stream channels, 41 square miles of lakes, and 2,182 miles of nearshore marine habitat.

8.26.5 Recovery Goals

The recovery plan consists of two documents: the Puget Sound salmon recovery plan (Shared Strategy for Puget Sound 2007) and a supplement by NMFS (2006d). The recovery plan adopts ESU and population level viability criteria recommended by the Puget Sound Technical Recovery Team (PSTRT) (Ruckelshaus et al. 2002). The PSTRT's biological recovery criteria will be met when all of the following conditions are achieved:

- The viability status of all populations in the ESU is improved from current conditions, and when considered in the aggregate, persistence of the ESU is assured;
- Two to four Chinook salmon populations in each of the five biogeographical regions of the ESU achieve viability, depending on the historical biological characteristics and acceptable risk levels for populations within each region;

- At least one population from each major genetic and life history group historically present within each of the five biogeographical regions is viable;
- Tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations are functioning in a manner that is sufficient to support an ESU-wide recovery scenario; Production of Chinook salmon from tributaries to Puget Sound not identified as primary freshwater habitat for any of the 22 identified populations occurs in a manner consistent with ESU recovery; and
- Populations that do not meet the viability criteria for all viable salmonid population parameters are sustained to provide ecological functions and preserve options for ESU recovery.

8.27 Chinook Salmon – Sacramento River Winter-Run ESU

The Sacramento River winter-run Chinook salmon ESU includes winter-run Chinook salmon spawning naturally in the Sacramento River and its tributaries, as well as winter-run Chinook salmon that are part of the conservation hatchery program at the Livingston Stone National Fish Hatchery (Figure 33). On January 4, 1994, NMFS listed the Sacramento River winter-run ESU of Chinook salmon as Endangered (59 FR 440).

8.27.1 Life History

Winter-run Chinook salmon are unique because they spawn during summer months when air temperatures usually approach their yearly maximum. As a result, winter-run Chinook salmon require stream reaches with cold water sources that will protect embryos and juveniles from the warm ambient conditions in summer. Adult winter-run Chinook salmon immigration and holding (upstream spawning migration) through the Delta and into the lower Sacramento River occurs from December through July, with a peak during the period extending from January through April (USFWS 1995). Winter-run Chinook salmon are sexually immature when upstream migration begins, and they must hold for several months in suitable habitat prior to spawning. Spawning occurs between late-April and mid-August, with a peak in June and July as reported by the California Division of Fish and Wildlife annual escapement surveys (2000 to 2006).

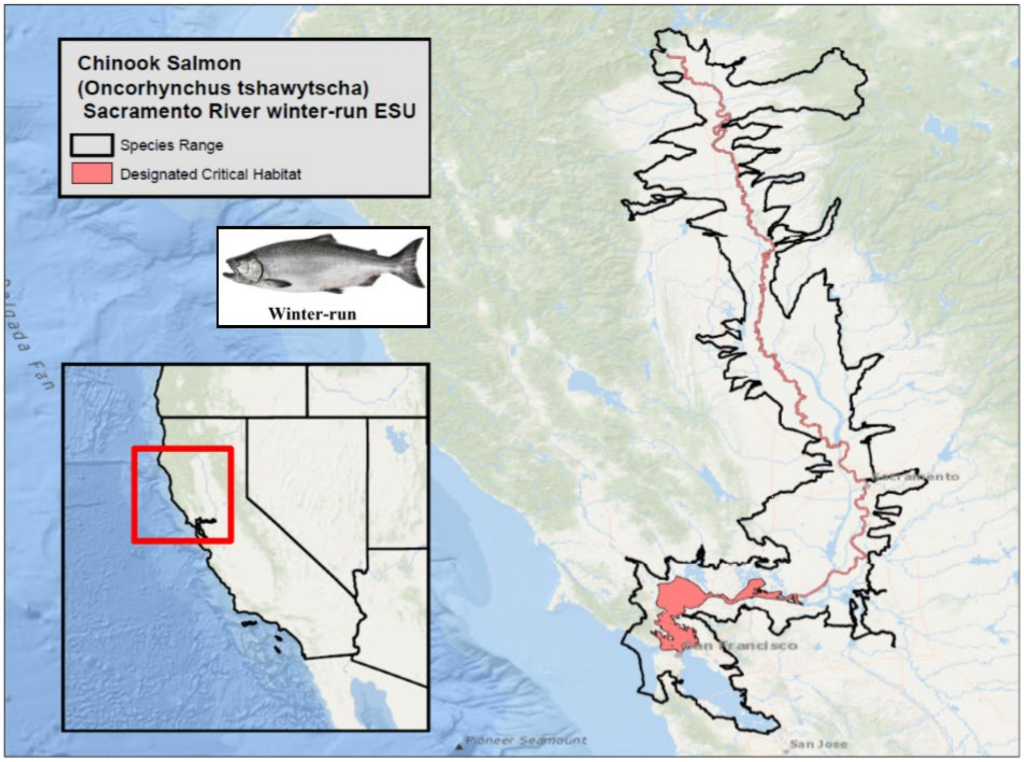

Figure 30. Geographic range and designated critical habitat of the Sacramento River winter-run ESU of Chinook salmon

Winter-run Chinook salmon embryo incubation in the Sacramento River can extend into October (Vogel et al. 1988). Winter-run Chinook salmon fry rearing in the upper Sacramento River exhibit peak abundance during September, with fry and juvenile emigration past the Red Bluff Diversion Dam primarily occurring from July through November (Poytress and Carrillo 2010; Poytress and Carrillo 2011; Poytress and Carrillo 2012). Emigration of winter-run Chinook salmon juveniles past Knights Landing, located approximately 155.5 river miles downstream of the Red Bluff Diversion Dam, reportedly occurs between November and March, peaking in December, with some emigration continuing through May in some years (Snider and Titus 2000).

The life history for this ESU of Chinook salmon is the same as presented in Section 8.23.1.

8.27.2 Population Dynamics

Over the last 10 years of available data (2003 to 2013), the abundance of spawning winter-run Chinook adults ranged from a low of 738 in 2011 to a high of 17,197 in 2007, with an average of 6,298 (NMFS 2011c). Current abundance estimates for the Sacramento winter-run ESU of Chinook salmon are found in Table 26 below.

Table 25. Average abundance estimates for Sacramento winter-run Chinook salmon natural- and hatchery-origin spawners 2013 to 2017 (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	210
Natural	Juvenile	195,354
Listed Hatchery Adipose Clip	Adult	2,232
Listed Hatchery Adipose Clip	Juvenile	200,000

The population declined from an escapement of near 100,000 in the late 1960s to fewer than 200 in the early 1990s (Good et al. 2005). More recent population estimates of 8,218 (2004), 15,730 (2005), and 17,153 (2006) show a three-year average of 13,700 returning winter-run Chinook salmon. However, the run size decreased to 2,542 in 2007 and 2,850 in 2008. Monitoring data indicated that approximately 5.6 percent of winter-run Chinook salmon eggs spawned in the Sacramento River in 2014 survived to the fry life stage (three to nearly 10 times lower than in previous years). The drought in 2015 made this another challenging year for winter-run Chinook salmon (NMFS 2016i).

The rising proportion of hatchery fish among returning adults threatens to increase the risk of extinction. Lindley et al. (2007) recommend that in order to maintain a low risk of genetic introgression with hatchery fish, no more than five percent of the naturally spawning population should be composed of hatchery fish. Since 2001, hatchery origin winter-run Chinook salmon have made up more than five percent of the run, and in 2005 the contribution of hatchery fish exceeded 18 percent (Lindley et al. 2007).

The range of winter-run Chinook salmon has been greatly reduced by Keswick and Shasta dams on the Sacramento River and by hydroelectric development on Battle Creek. Currently, winter-run Chinook salmon spawning is limited to the main-stem Sacramento River between Keswick Dam (River Mile [RM] 302) and the Red Bluff Diversion Dam (RM 243) where the naturally spawning population is artificially maintained by cool water releases from the dams. Within the Sacramento River, the spatial distribution of spawners is largely governed by water year type and the ability of the Central Valley Project to manage water temperatures (NMFS 2014b).

8.27.3 Status

The Sacramento River winter-run Chinook salmon ESU is composed of just one small population that is currently under severe stress caused by California's 2011 to 2017 drought, one of California's worst droughts on record. Current estimates of natural born adults are estimated to consist of 210 individuals. The population subsists in large part due to agency-managed cold-water releases from Shasta Reservoir during the summer and artificial propagation from Livingston Stone National Fish Hatchery's winter-run Chinook salmon conservation program.

Winter-run Chinook salmon are dependent on sufficient cold-water storage in Shasta Reservoir, and it has long been recognized that a prolonged drought had devastating impacts, possibly leading to the species' extinction. The probability of extended droughts is increasing as the effects of climate change continue (NMFS 2016b). In addition to drought, another important threat to winter-run Chinook salmon is a lack of suitable rearing habitat in the Sacramento River and Delta to allow for sufficient juvenile growth and survival (NMFS 2016b).

8.27.4 Critical Habitat

NMFS designated critical habitat for the Sacramento winter-run Chinook on June 16, 1993 (58 FR 33212).

8.27.5 Recovery Goals

Recovery goals, objectives and criteria for the Sacramento River winter-run Chinook are fully outlined in the 2014 Recovery Plan (NMFS 2014b). In order to achieve the downlisting criteria, the species would need to be composed of two populations – one viable and one at moderate extinction risk. Having a second population would improve the species' viability, particularly through increased spatial structure and abundance, but further improvement would be needed to reach the goal of recovery. To delist winter-run Chinook salmon, three viable populations are needed. Thus, the downlisting criteria represent an initial key step along the path to recovering winter-run Chinook salmon.

8.28 Chinook Salmon – Snake River Fall-Run ESU

The listed ESU currently includes all natural-origin fall-run Chinook salmon originating from the mainstem Snake River below Hells Canyon Dam (the lowest of three impassable dams that form the Hells Canyon Complex) and from the Tucannon River, Grande Ronde River, Imnaha River, Salmon River, and Clearwater River subbasins. The listed ESU also includes fall-run Chinook salmon from four artificial propagation programs (NMFS 2011b; NMFS 2015e) (Figure 34).

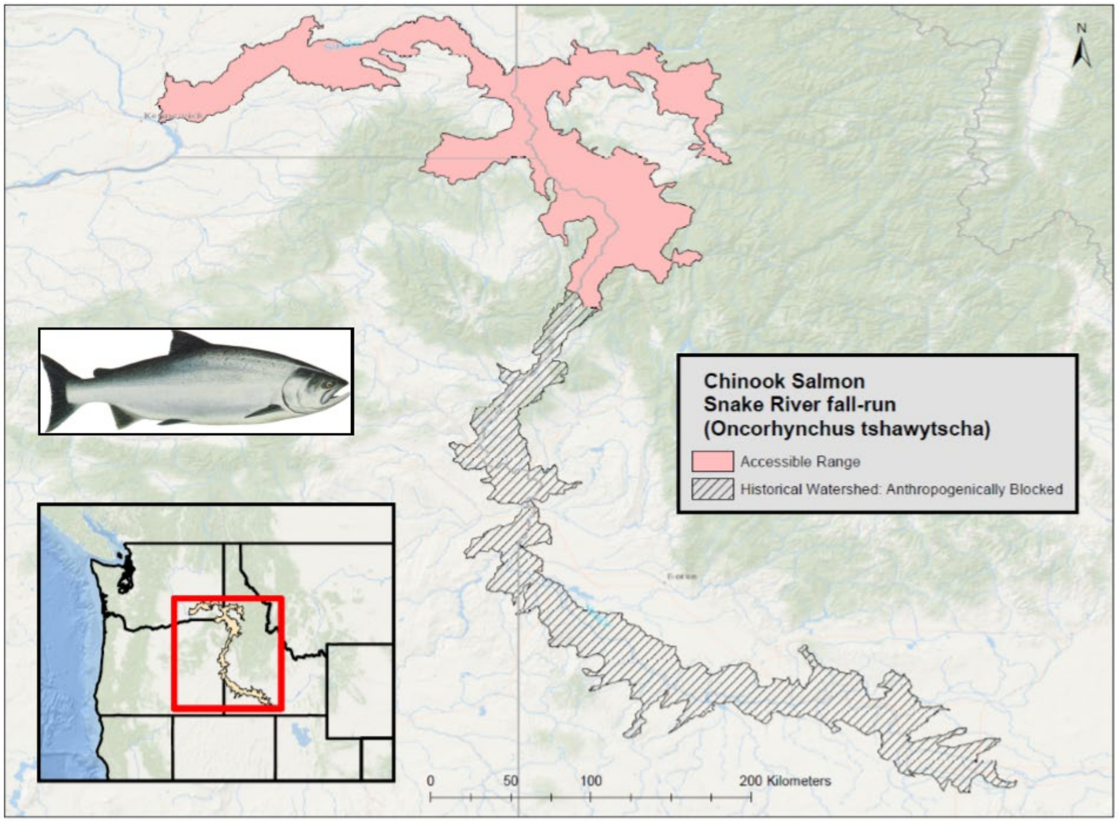

Figure 31. Geographic range of Snake River fall-run ESU Chinook salmon.

NMFS first listed Snake River fall Chinook salmon as a threatened species under the ESA on April 22, 1992 (57 FR 14658). NMFS reaffirmed the listing status in June 28, 2005 (70 FR 37160), and reaffirmed the status again in its 2014 (79 FR 20802).

8.28.1 Life History

Snake River fall-run Chinook return to the Columbia River in August and September, pass the Bonneville Dam from mid-August to the end of September, and enter the Snake River between early September and mid-October (DART 2013). Once they reach the Snake River, fall Chinook salmon generally travel to one of five major spawning areas and spawn from late October through early December (Connor et al. 2014).

Upon emergence from the gravel, most young fall Chinook salmon move to shoreline riverine habitat (NMFS 2015e). Some fall Chinook salmon smolts sustain active migration after passing Lower Granite Dam and enter the ocean as sub yearlings, whereas some delay seaward migration and enter the ocean as yearlings (Connor et al. 2005; McMichael et al. 2008; NMFS 2015e). Snake River fall Chinook salmon can be present in the estuary as juveniles in winter, as fry from March to May, and as fingerlings throughout the summer and fall (Fresh et al. 2005; Roegner et al. 2012; Teel et al. 2014).

Once in the Northern California Current, dispersal patterns differ for yearlings and sub yearlings. Sub yearlings migrate more slowly, are found closer to shore in shallower water, and do not disperse as far north as yearlings (Trudel et al. 2009; Tucker et al. 2011; Sharma and Quinn 2012; Fisher et al. 2014b). Snake River basin fall Chinook salmon spend one to four years in the Pacific Ocean, depending on gender and age at the time of ocean entry (Connor et al. 2005).

The life history for this ESU of Chinook salmon is the same as presented in Section 8.23.1.

8.28.2 Population Dynamics

The naturally spawning fall Chinook salmon in the lower Snake River have included both returns originating from naturally spawning parents and from returning hatchery releases. The geometric mean natural-origin adult abundance from 2005 to 2014 of annual spawner escapement estimates was 6,418, with a standard error of 0.19 (NMFS 2015e). Current abundance estimates for the Snake River fall-run ESU of Chinook salmon are presented in Table 27 below.

Table 26. Average Abundance Estimates for the Snake River Fall-Run ESU of Chinook Salmon from 2015 to 2019 (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	10,337
Natural	Juvenile	692,819
Listed Hatchery Adipose Clip	Adult	15,508
Listed Hatchery Adipose Clip	Juvenile	2,483,713
Listed Hatchery Intact Adipose	Adult	13,551
Listed Hatchery Intact Adipose	Juvenile	2,862,418

Past estimates of productivity for this population (1990 to 2009 brood years) was 1.53 with a standard error of 0.18. This estimate of productivity, however, may be problematic for two reasons: (1) the increasingly small number of years that actually contribute to the productivity estimate means that there is increasing statistical uncertainty surrounding that estimate, and (2) the years contributing to the estimate are now far in the past and may not accurately reflect the true productivity of the current population NMFS (2015e).

Genetic samples from the aggregate population in recent years indicate that composite genetic diversity is being maintained and that the Snake River Fall Chinook hatchery stock is similar to the natural component of the population, an indication that the actions taken to reduce the potential introgression of out-of-basin hatchery strays has been effective. Overall, the current genetic diversity of the population represents a change from historical conditions and, applying the ICTRT (McClure et al.) guidelines, the rating for this metric is moderate risk (NMFS 2015e).

The ICTRT identified three populations of this species, although only the lower mainstem population exists at present, and it spawns in the lower main stem of the Clearwater, Imnaha, Grande Ronde, Salmon, and Tucannon rivers. The extant population of Snake River fall-run

Chinook salmon is the only remaining population from an historical ESU that also included large mainstem populations upstream of the current location of the Hells Canyon Dam complex (ICTRT 2003; McClure et al. 2005). The population is at moderate risk for diversity and spatial structure (Ford 2011a).

8.28.3 Status

As late as the late 1800s, approximately 408,500 to 536,180 fall Chinook salmon are believed to have returned annually to the Snake River. The run began to decline in the late 1800s and then continued to decline through the early and mid-1900s as a result of overfishing and other human activities, including the construction of major dams. This ESU has one extant population. The extant population is at moderate risk for both diversity and spatial structure and abundance and productivity. The overall viability rating for this population is 'viable.' Overall, the status of Snake River fall Chinook salmon has clearly improved compared to the time of listing and compared to prior status reviews. The single extant population in the ESU is currently meeting the criteria for a rating of 'viable' developed by the ICTRT, but the ESU as a whole is not meeting the recovery goals described in the recovery plan for the species, which require the single population to be "highly viable with high certainty" and/or will require reintroduction of a viable population above the Hells Canyon Dam complex.

8.28.4 Critical Habitat

NMFS designated critical habitat for Snake River fall-run Chinook salmon on December 28, 1993 (58 FR 68543).

8.28.5 Recovery Goals

Recovery goals, objectives and criteria for the Snake River fall-run Chinook are fully outlined in the 2015 Recovery Plan (NMFS 2015e). The ESA recovery goal for Snake River fall-run Chinook salmon is that: the ecosystems upon which Snake River fall Chinook salmon depend are conserved such that the ESU is self-sustaining in the wild and no longer needs ESA protection.

8.29 Chinook Salmon – Snake River Spring/Summer-Run ESU

The Snake River spring/summer Chinook salmon ESU includes all naturally spawned populations of spring/summer Chinook salmon in the mainstem Snake River and the Tucannon River, Grand Ronde River, Imnaha River, and Salmon River subbasins (Figure 35). The ESU is broken into five MPG. Together, the MPGs contain 28 extant independent naturally spawning populations, three functionally extirpated populations, and one extirpated population. The Upper Salmon River MPG contains eight extant populations and one extirpated population. The Middle Fork Salmon River MPG contains nine extant populations. The South Fork Salmon River MPG contains four extant populations. The Grande Ronde/Imnaha Rivers MPG contains six extant populations, with two functionally extirpated populations. The Lower Snake River MPG contains one extant population and one functionally extirpated population. The South Fork and

Middle Fork Salmon Rivers currently support most of the natural spring/summer Chinook salmon production in the Snake River drainage (NMFS 2016g).

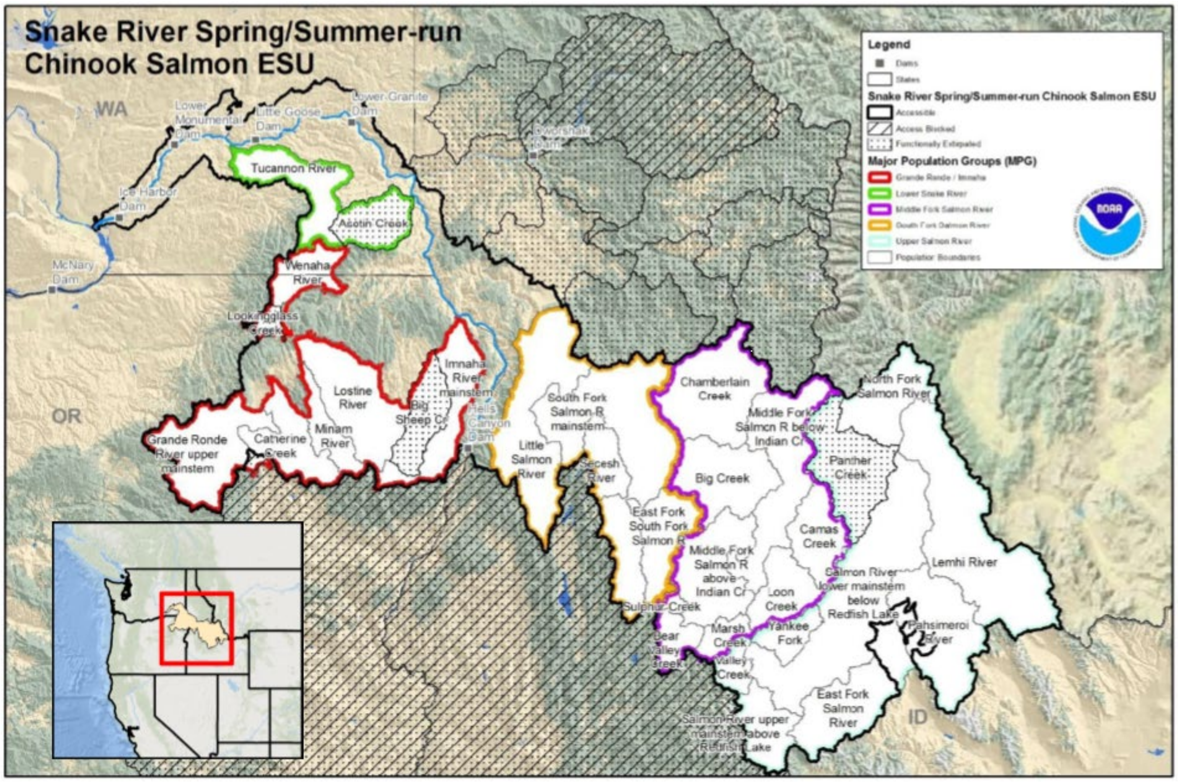

Figure 32. Geographic range and major population groups of Snake River spring/summer-run ESU Chinook salmon.

Snake River spring/summer-run Chinook salmon, an ESU was listed as a threatened species under the ESA on April 22, 1992 (57 FR 14658). NMFS reaffirmed the listing on June 28, 2005 (70 FR 37160) and made minor technical corrections to the listing on April 14, 2014 (79 FR 20802).

8.29.1 Life History

Adult spring-run Chinook salmon destined for the Snake River return to the Columbia River from the ocean in early spring and pass Bonneville Dam beginning in early March and ending May 31st. Snake River summer-run Chinook salmon return to the Columbia River from June through July. Adults from both runs hold in deep pools in the mainstem Columbia and Snake Rivers and the lower ends of the spawning tributaries until late summer, when they migrate into the higher elevation spawning reaches. Generally, Snake River spring-run Chinook salmon spawn in mid- through late August. Snake River summer-run Chinook salmon spawn approximately one month later than spring-run fish and tend to spawn lower in the tributary drainages, although their spawning areas often overlap with those of spring-run spawners.

The eggs that Snake River spring and summer Chinook salmon deposit in late summer and early fall incubate over the following winter, and hatch in late winter and early spring. Juveniles rear through the summer, overwinter, and typically migrate to sea in the spring of their second year of life, although some juveniles may spend an additional year in freshwater. Depending on the tributary and the specific habitat conditions, juveniles may migrate extensively from natal reaches into alternative summer-rearing or overwintering areas. Most yearling fish are thought to spend relatively little time in the estuary compared to sub-yearling ocean-type fish however there is considerable variation in residence times in different habitats and in the timing of estuarine and ocean entry among individual fish (McElhany et al. 2000; Holsman et al. 2012).

The life history for this ESU of Chinook salmon is the same as presented in Section 8.23.1.

8.29.2 Population Dynamics

This section includes abundance, population growth rate, and genetic diversity as it relates MPGs within the Snake River spring/summer-run ESU of Chinook salmon. Current abundance estimates of the Snake River spring/summer-run ESU of Chinook salmon are presented in Table 28 below.

Table 27. Average Abundance Estimates for the Snake River Spring/Summer-Run ESU of Chinook Salmon for 2014-2018 (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	12,798
Natural	Juvenile	1,296,641
Listed Hatchery Adipose Clip	Adult	2,387
Listed Hatchery Adipose Clip	Juvenile	4,760,250
Listed Hatchery Intact Adipose	Adult	421
Listed Hatchery Intact Adipose	Juvenile	868,679

Lower Snake River MPG: Abundance and productivity remain the major concern for the Tucannon River population. Natural spawning abundance (10-year geometric mean) has increased but remains well below the minimum abundance threshold for the single extant population in this MPG. Poor natural productivity continues to be a major concern. The integrated spatial structure/diversity risk rating for the Lower Snake River MPG is moderate.

Grande Ronde/Imnaha MPG: The Wenaha River, Lostine/Wallowa River and Minam River populations showed substantial increases in natural abundance relative to the previous ICTRT review, although each remains below their respective minimum abundance thresholds. The Catherine Creek and Upper Grande Ronde populations each remain in a critically depressed state. Geometric mean productivity estimates remain relatively low for all populations in the MPG. The Upper Grande Ronde population is rated at high risk for spatial structure and diversity while the remaining populations are rated at moderate.

South Fork Salmon River MPG: Natural spawning abundance (10-year geometric mean) estimates increased for the three populations with available data series. Productivity estimates for these populations are generally higher than estimates for populations in other MPGs within the ESU. Viability ratings based on the combined estimates of abundance and productivity remain at high risk, although the survival/capacity gaps relative to moderate and low risk viability curves are smaller than for other ESU populations. Spatial structure/diversity risks are currently rated moderate for the South Fork Mainstem population (relatively high proportion of hatchery spawners) and low for the Secesh River and East Fork South Fork populations.

Middle Fork Salmon River MPG: Natural-origin abundance and productivity remains extremely low for populations within this MPG. As in the previous ICTRT assessment, abundance and productivity estimates for Bear Valley Creek and Chamberlain Creek (limited data series) are the closest to meeting viability minimums among populations in the MPG. Spatial structure/diversity risk ratings for Middle Fork Salmon River MPG populations are generally moderate. This primarily is driven by moderate ratings for genetic structure assigned by the ICTRT because of uncertainty arising from the lack of direct genetic samples from within the component populations.

Upper Salmon River MPG: Abundance and productivity estimates for most populations within this MPG remain at very low levels relative to viability objectives. The Upper Salmon Mainstem has the highest relative abundance and productivity combination of populations within the MPG. Spatial structure/diversity risk ratings vary considerably across the Upper Salmon River MPG. Four of the eight populations are rated at low or moderate risk for overall spatial structure and diversity and could achieve viable status with improvements in average abundance/productivity. The high spatial structure/diversity risk rating for the Lemhi population is driven by a substantial loss of access to tributary spawning/rearing habitats and the associated reduction in life-history diversity. High-risk ratings for Pahsimeroi River, East Fork Salmon River, and Yankee Fork Salmon River are driven by a combination of habitat loss and diversity concerns related to low natural abundance combined with chronically high proportions of hatchery spawners in natural areas.

8.29.3 Status

The historical run of Chinook in the Snake River likely exceeded one million fish annually in the late 1800s, by the 1950s the run had declined to nearly 100,000 adults per year. The adult counts fluctuated throughout the 1980s but then declined further, reaching a low of 2,200 fish in 1995. Currently, the majority of extant spring/summer Chinook salmon populations in the Snake River spring/summer Chinook salmon ESU remain at high overall risk of extinction, with a low probability of persistence within 100 years. Factors cited in the 1991 status review as contributing to the species' decline since the late 1800s include overfishing, irrigation diversions, logging, mining, grazing, obstacles to migration, hydropower development, and questionable management practices and decisions (Matthews and Waples 1991). In addition, new threats such as those posed by toxic contamination, increased predation by non-native species, and effects due to climate change are emerging (NMFS 2016a).

8.29.4 Critical Habitat

Critical habitat for Snake River spring/summer Chinook salmon was designated on December 28, 1993 (58 FR 68543) and revised slightly on October 25, 1999 (64 FR 57399).

8.29.5 Recovery Goals

Recovery goals, scenarios and criteria for the Snake River spring and summer-run Chinook salmon are fully outlined in the 2016 proposed recovery plan (NMFS 2016g). The status levels targeted for populations within an ESU or DPS are referred to collectively as the "recovery scenario" for the ESU or DPS. NMFS has incorporated the viability criteria into viable recovery scenarios for each Snake River spring/summer Chinook salmon and steelhead MPG. The criteria should be met for an MPG to be considered viable or low (5 percent or less) risk of extinction, and thus contribute to the larger objective of ESU or DPS viability.

8.30 Chinook Salmon – Upper Columbia River Spring-Run ESU

The Snake River spring/summer Chinook salmon ESU includes all naturally spawned populations of spring/summer Chinook salmon in the mainstem Snake River and the Tucannon River, Grand Ronde River, Imnaha River, and Salmon River subbasins as well as spring/summer Chinook salmon from 11 artificial propagation programs (NMFS 2016g) (Figure 34).

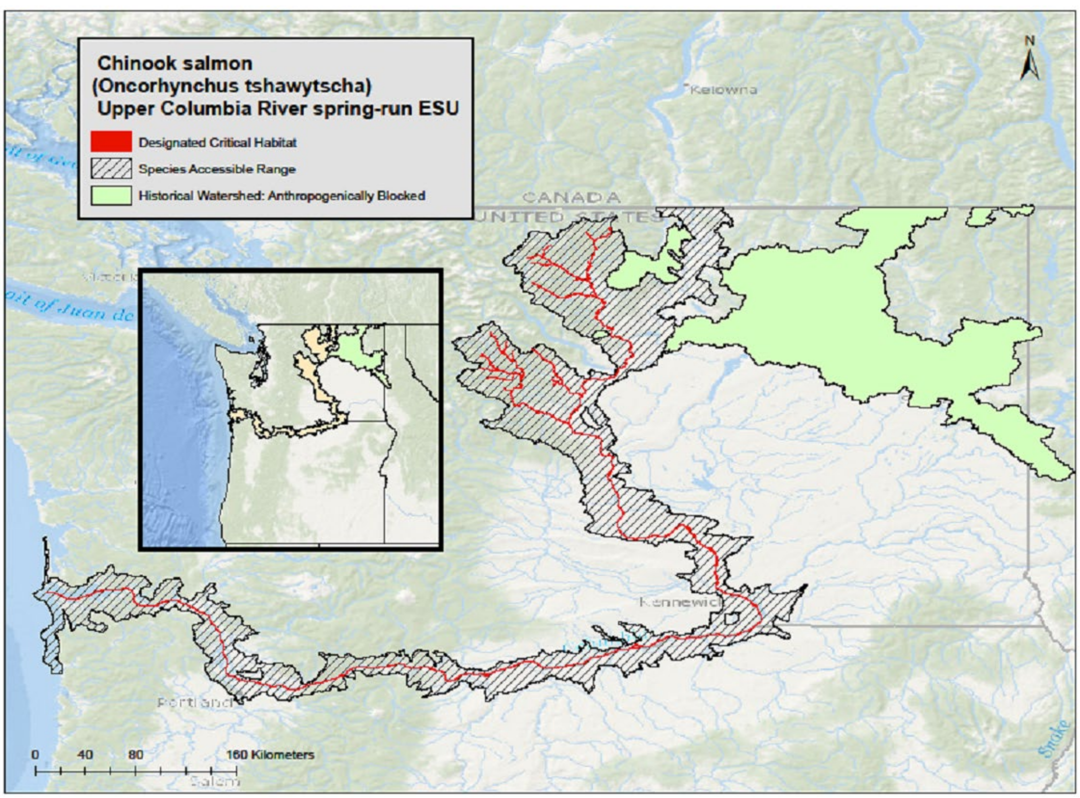

Figure 33. Geographic range and designated critical habitat of Chinook salmon, upper Columbia River ESU.

Upper Columbia River spring-run Chinook salmon, an ESU was listed as an endangered species under the ESA on March 24, 1999 (64 FR 14308). NMFS reaffirmed the listing on June 28, 2005 (70 FR 37160).

8.30.1 Life History

Adult Spring Chinook in the Upper Columbia Basin begin returning from the ocean in the early spring, with the run into the Columbia River peaking in mid-May. Spring Chinook enter the Upper Columbia tributaries from April through July. After migration, they hold in freshwater tributaries until spawning occurs in the late summer, peaking in mid to late August. Juvenile spring Chinook spend a year in freshwater before migrating to salt water in the spring of their second year of life. Most Upper Columbia spring Chinook return as adults after two or three years in the ocean. Some precocious males, or jacks, return after one winter at sea. A few other males mature sexually in freshwater without migrating to the sea. However, four and five year old fish that have spent two and three years at sea, respectively, dominate the run. Fecundity ranges from 4,200 to 5,900 eggs, depending on the age and size of the female.

The life history for this ESU of Chinook salmon is the same as presented in Section 8.23.1.

8.30.2 Population Dynamics

For all populations, average abundance over the recent 10-year period is below the average abundance thresholds that the ICTRT identifies as a minimum for low risk (ICTRT 2008b; ICTRT 2008a; ICTRT 2008c). The geometric mean spawning escapements from 1997 to 2001 were 273 for the Wenatchee population, 65 for the Entiat population, and 282 for the Methow population. These numbers represent only 8 percent to 15 percent of the minimum abundance thresholds. The 10-year geometric mean abundance of adult natural-origin spawners has increased for each population relative to the levels reported in the 2011 status review, but natural origin escapements remain below the corresponding ICTRT thresholds. Current abundance estimates of the upper Columbia River spring-run ESU of Chinook salmon are presented in Table 29 below.

Table 28. Five Year Average (2015 to 2020) Abundance Estimates for the Upper Columbia River Spring-Run ESU of Chinook Salmon (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	2,872
Natural	Juvenile	468,820
Listed Hatchery Adipose Clip	Adult	6,226
Listed Hatchery Adipose Clip	Juvenile	621,759

Listed Hatchery Intact Adipose	Adult	3,364
Listed Hatchery Intact Adipose	Juvenile	368,642

Overall abundance and productivity remains rated at high risk for each of the three extant populations in this MPG/ESU (NWFSC 2015b). The short-term lambda estimate for the Wenatchee River is 0.60; the Entiat River is 0.94; and the Methow River is 0.46.

The ICTRT characterizes the diversity risk to all Upper Columbia River Spring-run Chinook populations as "high". The high risk is a result of reduced genetic diversity from homogenization of populations that occurred under the Grand Coulee Fish Maintenance Project in 1939-1943.

Spring Chinook currently spawn and rear in the upper main Wenatchee River upstream from the mouth of the Chiwawa River, overlapping with summer Chinook in that area (Peven et al. 1994). The primary spawning areas of spring Chinook in the Wenatchee subbasin include Nason Creek and the Chiwawa, Little Wenatchee, and White rivers. The current spawning distribution for spring Chinook in the Entiat subbasin has been described as the Entiat River (river mile 16.2 to 28.9) and the Mad River (river mile 32 1.5-5.0) (NMFS 2007b). Spring Chinook of the Methow population currently spawn in the mainstem Methow River and the Twisp, Chewuch, and Lost drainages (NMFS 2007b). A few also spawn in Gold, Wolf, and Early Winters creeks.

8.30.3 Status

This ESU comprises four independent populations. Three are at high risk and one is functionally extirpated. Current estimates of natural origin spawner abundance increased relative to the levels observed in the prior review for all three extant populations, and productivities were higher for the Wenatchee and Entiat populations and unchanged for the Methow population. However, abundance and productivity remained well below the viable thresholds called for in the Upper Columbia Recovery Plan for all three populations. Although the status of the ESU is improved relative to measures available at the time of listing, all three populations remain at high risk (NWFSC 2015b).

8.30.4 Critical Habitat

NMFS designated critical habitat for Upper Columbia River Spring-run Chinook salmon on September 2, 2005 (70 FR 52630).

8.30.5 Recovery Goals

Recovery goals, objectives and detailed criteria for the Central Valley spring-run Chinook are fully outlined in the 2016 Recovery Plan. The general recovery objectives are:

- Increase the abundance of naturally produced spring Chinook spawners within each population in the Upper Columbia ESU to levels considered viable.

- Increase the productivity (spawner ratios and smolts/redds[3]) of naturally produced spring Chinook within each population to levels that result in low risk of extinction.
- Restore the distribution of naturally produced spring Chinook to previously occupied areas (where practical) and allow natural patterns of genetic and phenotypic diversity to be expressed.

8.31 Chinook Salmon – Upper Willamette River ESU

This evolutionarily significant unit, or ESU, includes naturally spawned spring-run Chinook salmon originating from the Clackamas River and from the Willamette River and its tributaries above Willamette Falls (Figure 35). Also, the Upper Willamette River spring-run ESU of Chinook salmon originate from six artificial propagation programs.

The upper Willamette River spring-run Chinook salmon ESU was listed as an endangered species under the ESA on March 24, 1999 (64 FR 14308). NMFS reaffirmed the listing on June 28, 2005 (70 FR 37160).

8.31.1 Life History

Upper Willamette River Chinook salmon exhibit an earlier time of entry into the Columbia River than other spring-run Chinook salmon ESUs (Myers et al. 1998b). Adults appear in the lower Willamette River in February, but the majority of the run ascends Willamette Falls in April and May, with a peak in mid- to late May. However, present-day salmon ascend the Willamette Falls via a fish ladder. Consequently, the migration of spring Chinook salmon over Willamette Falls extends into July and August (overlapping with the beginning of the introduced fall-run of Chinook salmon).

The adults hold in deep pools over summer and spawn in late fall or early winter when winter storms augments river flows. Fry may emerge from February to March and sometimes as late as June (Myers et al. 2006). Juvenile migration varies with three distinct juvenile emigration "runs": fry migration in late winter and early spring; sub-yearling (0 year +) migration in fall to early winter; and yearlings (1 year +) migrating in late winter to spring. Sub-yearlings and yearlings rear in the mainstem Willamette River where they also use floodplain wetlands in the lower Willamette River during the winter-spring floodplain inundation period.

[3] Gravel nests excavated by spawning females.

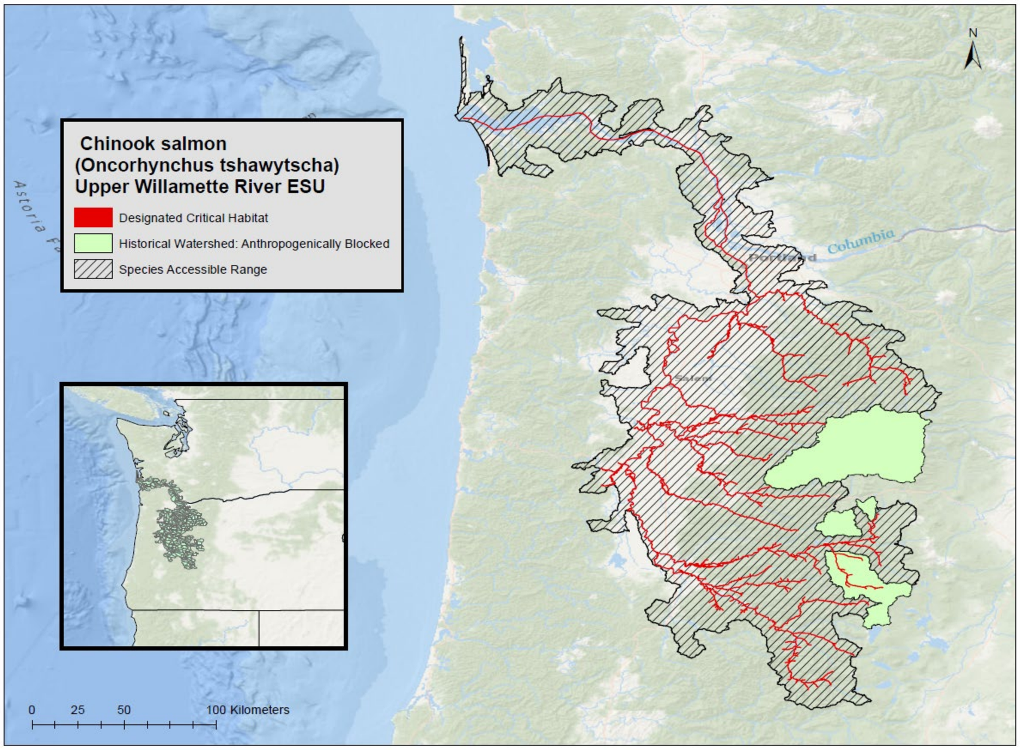

Figure 34. Geographic range and designated critical habitat of Chinook salmon, upper Willamette River ESU

The life history for this ESU of Chinook salmon is the same as presented in Section 8.23.1.

8.31.2 Population Dynamics

Abundance levels for five of the seven DIPs in this ESU remain well below their recovery goals. Of these, the Calapooia River may be functionally extinct and the Molalla River remains critically low (although perhaps only marginally better than the zero viable salmonid population score estimated in the Recovery Plan; (ODFW and NFMS 2011). Abundances in the North and South Santiam rivers have risen since the 2010 review, but still range only in the high hundreds of fish. The proportion of natural origin spawners improved in the North and South Santiam basins, but was still well below identified recovery goals. Improvement in the status of the Middle Fork Willamette River relates solely to the return of natural adults to Fall Creek; however, the capacity of the Fall Creek basin alone is insufficient to achieve the recovery goals for this DIP. The Clackamas and McKenzie Rivers have previously been viewed as natural population strongholds, but have both experienced declines in abundance despite having access to much of their historical spawning habitat. Overall, populations appear to be at either moderate or high risk, there has been likely little net change in the viable salmonid population score for the ESU since the last review, so the ESU remains at moderate risk (NWFSC 2015b). Current abundance estimates of the Upper Willamette River spring-run ESU of Chinook salmon are presented in Table 30 below.

Table 29. Average Abundance Estimates for the Upper Willamette River Spring-Run ESU of Chinook Salmon from 2014 to 2018 for Adults and 2015 to 2020 for Juveniles (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	10,203
Natural	Juvenile	1,275,681
Listed Hatchery Clipped and Intact Adipose	Adult	31,476
Listed Hatchery Adipose Clip	Juvenile	5,210,226
Listed Hatchery Intact Adipose	Juvenile	157

Access of fall-run Chinook salmon to the upper Willamette River and the mixing of hatchery stocks within the ESU have threatened the genetic integrity and diversity of the species. Much of the genetic diversity that existed between populations has been homogenized (Myers et al. 2006).

Radio-tagging results from 2014 suggest that few fish strayed into west-side tributaries (no detections) and relatively fewer fish were unaccounted for between Willamette Falls and the tributaries, 12.9 percent of clipped fish and 5.3 percent of unclipped fish (NWFSC 2015b). In contrast to most of the other populations in this ESU, McKenzie River Chinook salmon have access to much of their historical spawning habitat, although access to historically high quality habitat above Cougar Dam (South Fork McKenzie River) is still limited by poor downstream juvenile passage. Similarly, natural-origin returns to the Clackamas River have remained flat, despite adults having access to much of their historical spawning habitat.

8.31.3 Status

The Upper Willamette River Chinook ESU is considered to be extremely depressed, likely numbering less than 10,000 fish compared to a historical abundance estimate of 300,000 (NMFS 2011g). There are seven demographically independent populations of spring-run Chinook salmon in the Upper Willamette River Chinook salmon ESU: Clackamas, Molalla, North Santiam, South Santiam, Calapooia, McKenzie, and the Middle Fork Willamette (NMFS 2011g). The Clackamas and McKenzie Rivers have previously been viewed as natural population strongholds, but have both experienced declines in abundance despite having access to much of their historical spawning habitat. Juvenile spring Chinook produced by hatchery programs are released throughout many of the subbasins and adult Chinook returns to the ESU are typically 80 to 90 percent hatchery origin fish. Access to historical spawning and rearing areas is restricted by large dams in the four historically most productive tributaries, and in the absence of effective passage programs will continue to be confined to more lowland reaches where land development, water temperatures, and water quality may be limiting. Pre-spawning mortality levels are generally high in the lower tributary reaches where water temperatures and fish densities are generally the highest.

8.31.4 Critical Habitat

NMFS designated critical habitat for this species on September 2, 2005 (70 FR 52630).

8.31.5 Recovery Goals

Recovery goals, objectives and detailed criteria for the Upper Willamette River Chinook are fully outlined in the 2011 Recovery Plan (2011g). The 2011 recovery plan outlines five potential scenario options for meeting the viability criteria for recovery. Of the five scenarios, "scenario one" reportedly represented the most balanced approach given limitations in some populations. The approach in this scenario is to recover the McKenzie (core and genetic legacy population) and the Clackamas populations to an extinction risk status of very low risk (beyond minimal viability thresholds), to recover the North Santiam and Middle Fork Willamette populations (core populations) to an extinction risk status of low risk, to recover the South Santiam population to moderate risk, and improve the status of the remaining populations from very high risk to high risk.

8.32 Chum Salmon – Columbia River ESU

The Columbia River ESU of chum salmon includes naturally spawned chum salmon originating from the Columbia River and its tributaries in Washington and Oregon (Figure 36), and also chum salmon from two artificial propagation programs.

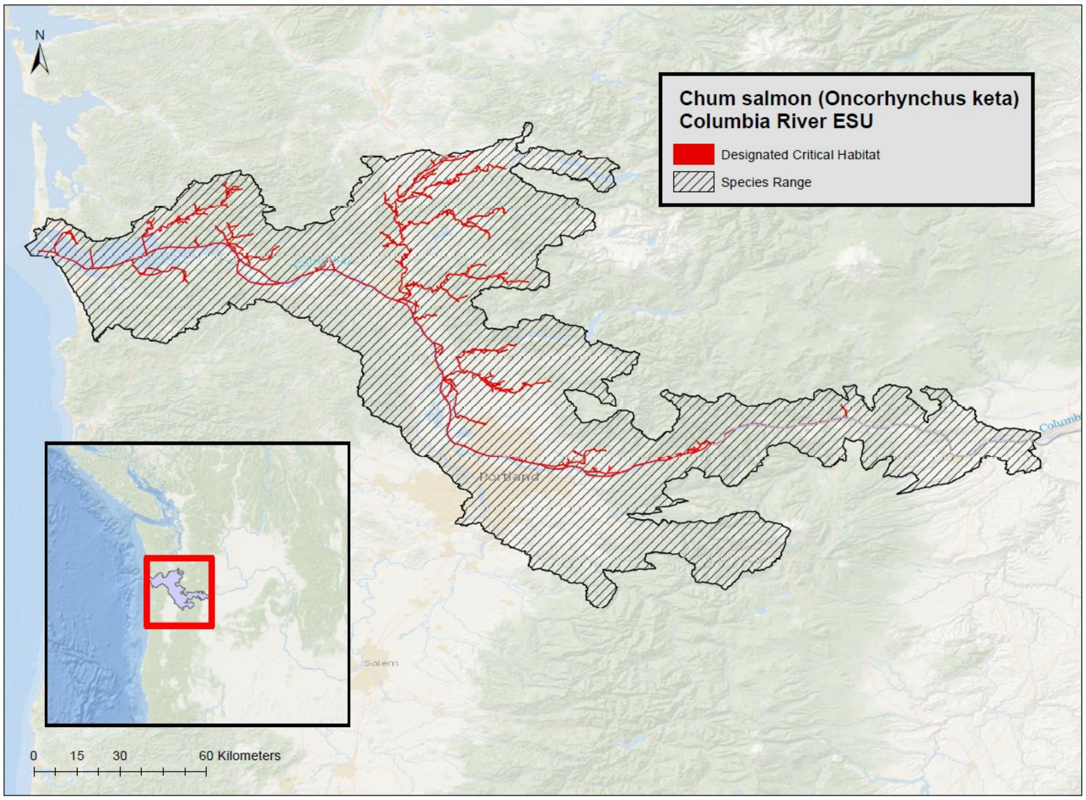

Figure 35. Geographic range and designated critical habitat of chum salmon, Columbia River ESU.

Chum salmon are an anadromous (i.e., adults migrate from marine to freshwater streams and rivers to spawn) and semelparous (i.e., they spawn once and then die) fish species. Adult chum salmon are typically between eight and fifteen pounds, but they can get as large as 45 pounds and 3.6 feet long. Males have enormous canine-like fangs and a striking calico pattern body color (front two-thirds of the flank marked by a bold, jagged, reddish line and the posterior third by a jagged black line) during spawning. Females are less flamboyantly colored and lack the extreme dentition of the males. Ocean stage chum salmon are metallic greenish-blue along the back with black speckles. Chum salmon have the widest natural geographic and spawning distribution of the Pacific salmonids. On March 25, 1999, NMFS listed the Hood Canal summer-run ESU and the Columbia River ESU of chum salmon as threatened (64 FR 14508). NMFS reaffirmed the status of these two ESUs as threatened on June 28, 2005 (70 FR 37160).

8.32.1 Life History

Most chum salmon mature and return to their birth stream to spawn between three and five years of age, with 60 to 90 percent of the fish maturing at four years of age. Age at maturity appears to follow a latitudinal trend (i.e., greater in the northern portion of the species' range). Chum salmon typically spawn in the lower reaches of rivers, with redds usually dug in the mainstem or in side channels of rivers from just above tidal influence to 100 kilometers from the sea. Juveniles out-migrate to seawater almost immediately after emerging from the gravel covered redds (Salo 1991b). The survival and growth in juvenile chum salmon depend less on freshwater conditions (unlike stream-type salmonids which depend heavily on freshwater habitats) than on favorable estuarine conditions. Chum salmon form schools, presumably to reduce predation (Pitcher 1986), especially if their movements are synchronized to swamp predators (Miller and Brannon 1982).

Chum salmon spend two to five years in feeding areas in the northeast Pacific Ocean, which is a greater proportion of their life history compared to other Pacific salmonids. Chum salmon distribute throughout the North Pacific Ocean and Bering Sea, although North American chum salmon (as opposed to chum salmon originating in Asia), rarely occur west of 175 East longitude (Johnson et al. 1997a). North American chum salmon migrate north along the coast in a narrow band that broadens in southeastern Alaska, although some data suggests that chum may travel directly offshore into the north Pacific Ocean (Johnson et al. 1997a).

8.32.2 Population Dynamics

Chum populations in the Columbia River historically reached hundreds of thousands to a million adults each year (NMFS 2017a). In the past 50 years, the average has been a few thousand a year. The majority of populations in the Columbia River chum ESU remain at high to very high risk, with very low abundances (NWFSC 2015b). Ford (2011b) concluded that 14 out of 17 of chum populations in this ESU were either extirpated or nearly extirpated. Current abundance estimates of the Columbia River ESU of chum salmon are presented in Table 31 below.

Table 30. Abundance Estimates for the Columbia River ESU of Chum Salmon (NMFS 2020).

Production	Life Stage	Abundance
Natural	Adult	10,644
Natural	Juvenile	6,626,218
Listed Hatchery Intact Adipose	Adult	426
Listed Hatchery Intact Adipose	Juvenile	601,503

Only one population (Grays River) is at low risk, with spawner abundances in the thousands, and demonstrating a recent positive trend. Two other populations (Washougal River and Lower Gorge) maintain moderate numbers of spawners and appear to be relatively stable (NWFSC 2015b). The overall trend since 2000 is negative, with the recent peak in abundance (2010 to 2011) being considerably lower than the previous peak in 2002.

There are currently four hatchery programs in the Lower Columbia River releasing juvenile chum salmon: Grays River Hatchery, Big Creek Hatchery, Lewis River Hatchery, and Washougal Hatchery (NMFS 2017a). Total annual production from these hatcheries has not exceeded 500,000 fish. All of the hatchery programs in this ESU use integrated stocks developed to supplement natural production. Other populations in this ESU persist at very low abundances and the genetic diversity available would be very low (NWFSC 2015b). Diversity has been greatly reduced at the ESU level because of presumed extirpations and low abundance in the remaining populations (fewer than 100 spawners per year for most populations) (LCFRB 2010; NMFS 2013a).

The Columbia River chum salmon ESU includes all natural-origin chum salmon in the Columbia River and its tributaries in Washington and Oregon. The ESU consists of three populations: Grays River, Hardy Creek and Hamilton Creek in Washington State. Chum salmon from four artificial propagation programs also contribute to this ESU.

8.32.3 Status

The majority of the populations within the Columbia River chum salmon ESU are at high to very high risk, with very low abundances (NWFSC 2015b). These populations are at risk of extirpation due to demographic stochasticity and Allee effects. One population, Grays River, is at low risk, with spawner abundances in the thousands and demonstrating a recent positive trend. The Washougal River and Lower Gorge populations maintain moderate numbers of spawners and appear to be relatively stable. The life history of chum salmon is such that ocean conditions have a strong influence on the survival of emigrating juveniles. The potential prospect of poor ocean conditions for the near future may put further pressure on the Columbia River chum salmon ESU (NWFSC 2015b). Freshwater habitat conditions may be negatively influencing spawning and early rearing success in some basins, and contributing to the overall low productivity of the ESU. Columbia River chum salmon were historically abundant and subject to substantial harvest until the 1950s (NWFSC 2015b). There is no directed harvest of this ESU and the incidental harvest rate has been below one percent for the last five years (NWFSC 2015b). Land development, especially in the low gradient reaches that chum salmon prefer, will continue to be a threat to most chum salmon populations due to projected increases in the population of the greater Vancouver-Portland area and the Lower Columbia River overall (Metro 2015). The Columbia River chum salmon ESU remains at a moderate to high risk of extinction (NWFSC 2015b).

8.32.4 Critical Habitat

NMFS designated critical habitat for the Columbia River chum salmon ESU in 2005 (70 FR 52630). This designation includes defined areas in the following subbasins: Middle Columbia/Hood, Lower Columbia/Sandy, Lewis, Lower Columbia/Clatskanie, Lower Cowlitz, and Lower Columbia sub-basin and river corridor (Figure 36).

8.32.5 Recovery Goals

The ESU recovery strategy for Columbia River chum salmon focuses on improving tributary and estuarine habitat conditions, reducing or mitigating hydropower impacts, and reestablishing chum salmon populations where they may have been extirpated (NMFS 2013b). The goal of the strategy is to increase the abundance, productivity, diversity, and spatial structure of chum salmon populations such that the Coast and Cascade chum salmon strata are restored to a high probability of persistence and the persistence probability of the two Gorge populations improves. For details on Columbia River chum salmon ESU recovery goals, including complete down-listing/delisting criteria, see the NMFS 2013 recovery plan (NMFS 2013b).

8.33 Chum Salmon – Hood Canal Summer-Run ESU

The chum salmon, Hood Canal summer-run ESU includes naturally spawned summer-run chum salmon originating from Hood Canal and its tributaries as well as from Olympic Peninsula rivers between Hood Canal and Dungeness Bay (Figure 37). Also, summer-run chum salmon originate from four artificial propagation programs.

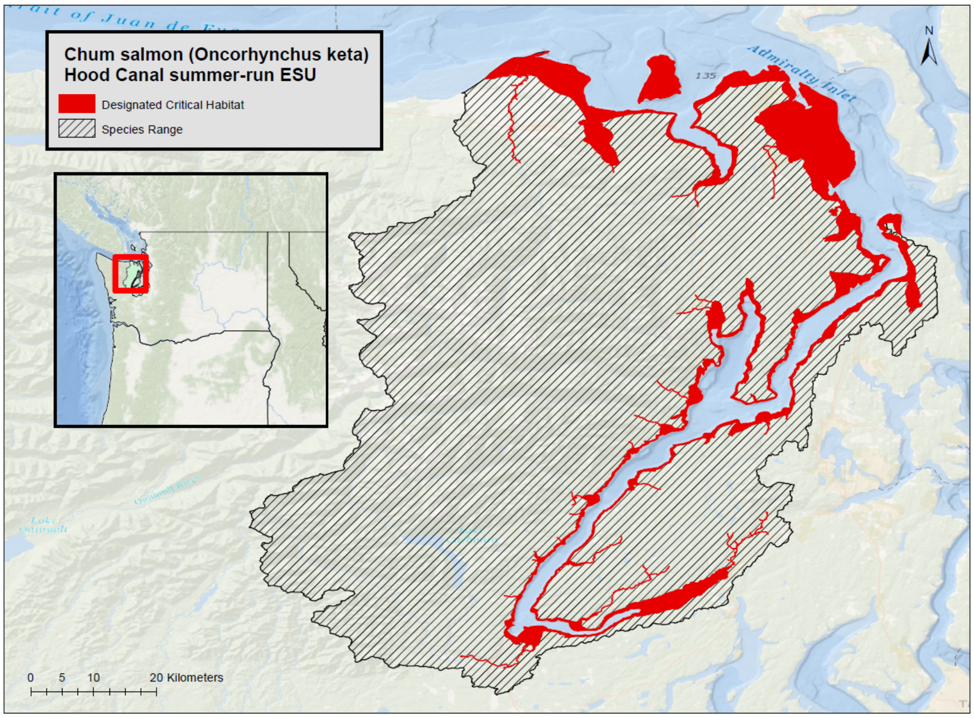

Figure 36. Geographic range and designated critical habitat of chum salmon, Hood Canal ESU.

Chum salmon are anadromous (i.e., adults migrate from marine to freshwater streams and rivers to spawn) and semelparous (i.e., they spawn once and then die) fish species. Adult chum salmon are typically between eight and fifteen pounds, but they can get as large as 45 pounds and 3.6 feet long. Males have enormous canine-like fangs and a striking calico pattern body color (front two-thirds of the flank marked by a bold, jagged, reddish line and the posterior third by a jagged black line) during spawning. Females are less flamboyantly colored and lack the extreme dentition of the males. Ocean stage chum salmon are metallic greenish-blue along the back with black speckles. Chum salmon have the widest natural geographic and spawning distribution of the Pacific salmonids. On March 25, 1999, NMFS listed the Hood Canal Summer-run ESU and the Columbia River ESU of chum salmon as threatened (64 FR 14508). NMFS reaffirmed the status of these two ESUs as threatened on June 28, 2005 (70 FR 37160).

8.33.1 Life History

Chum life history is described in section 8.32.1.

8.33.2 Population Dynamics

Of the sixteen populations that comprise the Hood Canal Summer-run chum ESU, seven are considered "functionally extinct" (Skokomish, Finch Creek, Anderson Creek, Dewatto, Tahuya, Big Beef Creek and Chimicum). NMFS examined average escapements (geometric means) for five-year intervals and estimated trends over the intervals for all natural spawners and for natural-origin only spawners. For both populations, abundance was relatively high in the 1970s, lowest for the period 1985 to 1999, and high again from 2005 to 2015 (NWFSC 2015b). Current abundance estimates of the Hood Canal summer-run ESU of chum salmon are presented in Table 32 and Table 33 below.

Table 31. Hood Canal summer-run juvenile chum salmon hatchery releases (NMFS 2020).

Sub-basin	Artificial propagation program	Brood year	Run Timing	Clipped Adipose Fin	Intact Adipose Fin
Hood Canal	LLTK – Lilliwaup	2018	Summer	-	150,000
Total Annual Release Number				-	150,000

Table 32. Abundance of natural-origin and hatchery-origin Hood Canal summer-run chum salmon spawners in escapements 2013 to 2017 (NMFS 2020).

Population Name	Natural-origin Spawners[a]	Hatchery-origin Spawners[b]	% Hatchery Origin	Expected Number of Outmigrants[c]
Strait of Juan de Fuca Population				
Jimmycomelately Creek	1,288	0	0.00%	188,313
Salmon Creek	1,836	0	0.00%	268,531
Snow Creek	311	0	0.00%	45,541
Chimacum Creek	902	0	0.00%	131,971
Population Average[d]	4,337	0	0.00%	634,355
Hood Canal Population				
Big Quilcene River	6,437	0	0.00%	941,450

Population Name	Natural-origin Spawners[a]	Hatchery-origin Spawners[b]	% Hatchery Origin	Expected Number of Outmigrants[c]
Little Quilcene River	122	0	0.00%	17,795
Big Beef Creek	10	0	0.00%	1,532
Dosewallips River	2,021	0	0.00%	295,524
Duckabush River	3,172	0	0.00%	463,856
Hamma River	2,944	10	0.34%	432,056
Anderson Creek	3	0	0.00%	376
Dewatto River	95	0	0.00%	13,947
Lilliwaup Creek	857	1,141	57.10%	292,159
Tahuya River	205	299	59.36%	73,777
Union River	2,789	2	0.07%	408,166
Skokomish River	2,154	0	0.00%	314,960
Population Average[d]	20,809	1,452	6.52%	3,255,599
ESU Average	25,146	1,452	5.46%	3,889,955

a Five-year geometric mean of post fishery natural-origin spawners (2015 to 2019).

b Five-year geometric mean of post fishery hatchery-origin spawners (2015 to 2019).

c Expected number of outmigrants=Total spawners*45% proportion of females*2,500 eggs per female*13% survival rate from egg to outmigrant.

d Averages are calculated as the geometric mean of the annual totals (2015 to 2019).

The overall trend in spawning abundance is generally stable for the Hood Canal population (all natural spawners and natural-origin only spawners) and for the Strait of Juan de Fuca population (all natural spawners). Productivity rates, which were quite low during the five-year period from 2005 to 2009 (Ford 2011b), increased from 2011 to 2015 and were greater than replacement rates from 2014-2015 for both MPGs (NWFSC 2015b).

There were likely at least two ecological diversity groups within the Strait of Juan de Fuca population and at least four ecological diversity groups within the Hood Canal population. With the possible exception of the Dungeness River aggregation within the Strait of Juan de Fuca population, Hood Canal ESU summer chum spawning groups exist today that represent each of the ecological diversity groups within the two populations (NMFS 2017a). Diversity values (Shannon diversity index) were generally lower in the 1990s for both independent populations within the ESU, indicating that most of the abundance occurred at a few spawning sites (NWFSC

2015b). Although the overall linear trend in diversity appears to be negative, the last five-year interval shows the highest average value for both populations within the Hood Canal ESU.

The Hood Canal summer-run chum salmon ESU includes all naturally spawned populations of summer-run chum salmon in Hood Canal and its tributaries as well as populations in Olympic Peninsula rivers between Hood Canal and Dungeness Bay, Washington. The nine populations are well distributed throughout the ESU range except for the eastern side of Hood Canal (Johnson et al. 1997a). Two independent MPGs have been identified for this ESU: (1) spawning aggregations from rivers and creeks draining into the Strait of Juan de Fuca, and (2) spawning aggregations within Hood Canal proper (Sands 2009).

8.33.3 Status

The two most recent status reviews (2011 and 2015) indicate some positive signs for the Hood Canal summer-run chum salmon ESU. Diversity has increased from the low levels seen in the 1990s due to both the reintroduction of spawning aggregates and the more uniform relative abundance between populations; considered a good sign for viability in terms of spatial structure and diversity (Ford 2011b). Spawning distribution within most streams was also extended further upstream with increased abundance. At present, spatial structure and diversity viability parameters for each population nearly meet the viability criteria (NWFSC 2015b). Spawning abundance has remained relatively high compared to the low levels observed in the early 1990's (Ford 2011b). Natural-origin spawner abundance has shown an increasing trend since 1999, and spawning abundance targets in both populations were met in some years (NWFSC 2015b). Despite substantive gains towards meeting viability criteria in the Hood Canal and Strait of Juan de Fuca summer chum salmon populations, the ESU still does not meet all of the recovery criteria for population viability at this time (NWFSC 2015b). Overall, the Hood Canal Summer-run chum salmon ESU remains at a moderate risk of extinction.

8.33.4 Critical Habitat

NMFS designated critical habitat for Hood Canal summer-run chum salmon in 2005 (70 FR 52630) and includes 79 miles of stream channels and 377 miles of nearshore marine habitat (Figure 37).

8.33.5 Recovery Goals

The recovery strategy for Hood Canal Summer-run chum salmon focuses on habitat protection and restoration throughout the geographic range of the ESU, including both freshwater habitat and nearshore marine areas within a one-mile radius of the watersheds' estuaries (NMFS 2007a). The recovery plan includes an ongoing harvest management program to reduce exploitation rates, a hatchery supplementation program, and the reintroduction of naturally spawning summer chum aggregations to several streams where they were historically present. The Hood Canal plan gives first priority to protecting the functioning habitat and major production areas of the ESU's eight extant stocks, keeping in mind the biological and habitat needs of different life-history stages, and second priority to restoration of degraded areas, where recovery of natural processes appears to be feasible (HCCC 2005). For details on Hood Canal Summer-run chum salmon ESU recovery goals, including complete down-listing/delisting criteria, see the Hood Canal Coordinating Council 2005 recovery plan (HCCC 2005) and the NMFS 2007 supplement to this recovery plan (NMFS 2007a).

8.34 Coho Salmon – Central California Coast ESU

This evolutionarily significant unit, or ESU, includes naturally spawned Coho salmon originating from rivers south of Punta Gorda, California up to and including Aptos Creek, as well as such Coho salmon originating from tributaries to San Francisco Bay. Also, Coho salmon from three artificial propagation programs are included in this ESU (Figure 40).

Coho salmon are an anadromous species (i.e., adults migrate from marine to freshwater streams and rivers to spawn). Adult Coho salmon are typically about two feet long and eight pounds. Coho have backs that are metallic blue or green, silver sides, and light bellies; spawners are dark with reddish sides; and when Coho salmon are in the ocean, they have small black spots on the back and upper portion of the tail. Central California Coast Coho salmon, an ESU was listed as threatened under the ESA on October 31, 1996 (64 FR 56138). NMFS re-classified the ESU as endangered on June 28, 2005 (70 FR 37160).

8.34.1 Life History

Central California Coast Coho salmon typically enter freshwater from November through January, and spawn into February or early March (Moyle 2002b). The upstream migration towards spawning areas coincides with large increases in stream flow (Hassler 1987). Coho salmon often are not able to enter freshwater until heavy rains have caused breaching of sand bars that form at the mouths of many coastal California streams. Spawning occurs in streams with direct flow to the ocean, or in large river tributaries (Moyle 2002b). Female Coho salmon choose a site to spawn at the head of a riffle, just downstream of a pool where water flow changes from slow to turbulent, and where medium to small size gravel is abundant (Moyle 2002b).

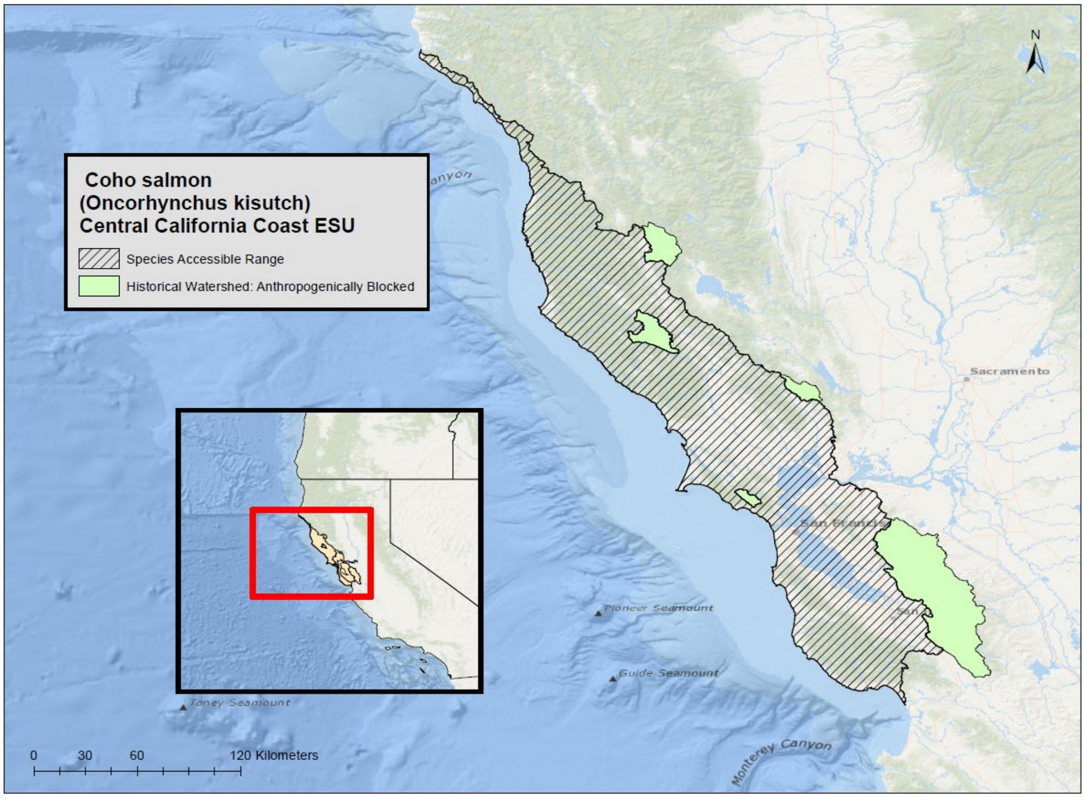

Figure 37. Geographic range of Coho salmon, Central California Coast ESU.

Eggs incubate in redds from November through April, and hatch into alevins after a period of 35 to 50 days (Shapovalov and Taft 1954). The period of incubation is inversely related to water temperature. Alevins remain in the gravel for two to ten weeks then emerge into the water column as young juveniles, known as fry. Juveniles, or fry, form schools in shallow water along the undercut banks of the stream to avoid predation. The juveniles feed heavily during this time, and as they grow they set up individual territories. Juveniles are voracious feeders, ingesting any organism that moves or drifts over their holding area. The juvenile's diet is mainly aquatic insect larvae and terrestrial insects, but small fish are taken when available (Moyle 2002b).

After one year in freshwater juvenile Coho salmon undergo physiological transformation into smolts for outmigration to the ocean. Smolts may spend time residing in the estuarine habitat prior to ocean entry, to allow for the transition to the saline environment. After entering the ocean, the immature salmon initially remain in the nearshore waters close to their natal stream. They gradually move northward, generally staying over the continental shelf (Brown et al. 1994). After approximately two years at sea, adult Coho salmon move slowly homeward. Adults begin their freshwater migration upstream after heavy fall or winter rains breach the sandbars at the mouths of coastal streams (Sandercock 1991) and/or flows are sufficient to reach upstream spawning areas.

8.34.2 Population Dynamics

Limited information exists on the abundance of Coho salmon within the Central California Coast ESU. About 200,000 to 500,000 Coho salmon were produced statewide in the 1940s (Good et al. 2005). This escapement declined to about 99,000 by the 1960s with approximately 56,000 (56 percent) originating from streams within the Central California Coast ESU. The estimated number of Coho salmon produced within the ESU in 2011 was between 2,000 and 3,000 wild adults (Gallagher et al. 2010). Current abundance estimates of the Central California Coast ESU of Coho salmon are presented in Table 34 and Table 35 below.

Table 33. Average juvenile Central California Coast Coho salmon Coho salmon hatchery releases (NMFS 2020).

Artificial propagation program	Watershed	Years	Clipped Adipose Fin
Don Clausen Fish Hatchery Captive Broodstock Program	Russian River tributaries	2014-2018	132,680
Scott Creek/King Fisher Flats Conservation Program	Gazos and San Vicente creeks	2018	12,000
Scott Creek Captive Broodstock Program	Scott Creek	2013-2017	21,200
Average Annual Release Number			165,880

Table 34. Geometric mean abundances of Central California Coast Coho salmon spawner escapements by population. Populations in bold font are independent populations (NMFS 2020).

Stratum	Population	Spawners		Expected Number of Outmigrants[b]
		Natural-origin	Hatchery-origin[a]	
Lost Coast – Navarro Point	Ten Mile River	69	-	4,830
	Usal Creek	4	-	280
	Noyo River	455	-	31,850
	Pudding Creek	184	-	12,880
	Caspar Creek	40	-	2,800
	Big River	183	-	12,810
	Little River	30		2,100

Stratum	Population	Spawners		Expected Number of Outmigrants[b]
		Natural-origin	Hatchery-origin[a]	
	Albion River	21	-	1,470
	Big Salmon Creek	3		210
Navarro Point – Gualala Point	Navarro River	102	-	7,140
	Greenwood Creek	3		210
	Garcia River	18	-	1,260
	Gualala River	-	-	-
Coastal	Russian River	364[c]	323	48,090
	Salmon Creek	-	-	-
	Walker Creek		-	-
	Lagunitas Creek	408	-	28,560
	Pine Gulch	2		140
	Redwood Creek	23	-	1,610
Santa Cruz Mountains	Pescadero Creek	1	-	70
	San Lorenzo River	1	-	70
	Waddell Creek	1	-	70
	Scott Creek	18	4	1,540
	San Vicente Creek	2	-	140
	Soquel Creek	-	-	-
ESU Total		1,932	327	158,130

a J. Jahn, pers. comm., July 2, 2013

b Expected number of outmigrants=Total spawners*50% proportion of females*2,000 eggs per female*7% survival rate from egg to outmigrant

c Arithmetic mean used due to unavailability of geometric mean

Within the Lost Coast – Navarro Point stratum and the Navarro Point – Gualala Point stratum, most independent populations show positive but non-significant population trends. Dependent populations within these stratums have declined significantly since 2011. In the Russian River and Lagunitas Creek watersheds, which are the two largest within the Central Coast strata, recent Coho salmon population trends suggest limited improvement, although both populations remain well below recovery targets. Recent sampling within Pescadero Creek and San Lorenzo River, the only two independent populations within the Santa Cruz Mountains strata, suggest Coho salmon have likely been extirpated within both basins.

Genetic studies show little homogenization of populations, i.e., transfer of stocks between basins have had little effect on the geographic genetic structure of central California Coast Coho salmon (Sonoma County Water Agency (SCWA) 2002). This ESU likely has considerable diversity in local adaptations given that the ESU spans a large latitudinal diversity in geology and ecoregions, and include both coastal and inland river basins.

The Technical Review Team identified 11 "functionally independent", one "potentially independent" and 64 "dependent" populations in the Central California Coast ESU of Coho salmon (Bjorkstedt et al., 2005 with modifications described in Spence et al. 2008). The 75 populations were grouped into five Diversity Strata. The Russian River is of particular importance for preventing the extinction and contributing to the recovery of the Central California Coast Coho salmon ESU (NOAA 2013). The Russian River population, once the largest and most dominant source population in the ESU, is now at high risk of extinction because of low abundance and failed productivity (Spence, Bjorkstedt et al. 2008). The Lost Coast and Navarro Point contain the majority of Coho salmon remaining in the ESU.

8.34.3 Status

The low survival of juveniles in freshwater, in combination with poor ocean conditions, has led to the precipitous declines of Central California Coast ESU Coho salmon populations. Most independent populations remain at critically low levels, with those in the southern Santa Cruz Mountains strata likely extirpated. Data suggest some populations show a slight positive trend in annual escapement, but the improvement is not statistically significant. Overall, all populations remain, at best, a slight fraction of their recovery target levels, and, aside from the Santa Cruz Mountains strata, the continued extirpation of dependent populations continues to threaten the ESU's future survival and recovery.

8.34.4 Critical Habitat

Critical habitat for the Central California Coast ESU of Coho salmon was designated on May 5, 1999 (64 FR 24049).

8.34.5 Recovery Goals

See the 2012 Recovery Plan for complete down listing/delisting criteria for each of the following recovery goals (NMFS 2012a):

- Prevent extinction by protecting existing populations and their habitats;
- Maintain current distribution of Coho salmon and restore their distribution to previously occupied areas essential to their recovery;
- Increase abundance of Coho salmon to viable population levels, including the expression of all life history forms and strategies;

- Conserve existing genetic diversity and provide opportunities for interchange of genetic material between and within meta populations;
- Maintain and restore suitable freshwater and estuarine habitat conditions and characteristics for all life history stages so viable populations can be sustained naturally;
- Ensure all factors that led to the listing of the species have been ameliorated; and
- Develop and maintain a program of monitoring, research, and evaluation that advances understanding of the complex array of factors associated with Coho salmon survival and recovery and which allows for adaptively managing our approach to recovery over time.

8.35 Coho Salmon – Lower Columbia River ESU

This ESU includes naturally spawned Coho salmon originating from the Columbia River and its tributaries downstream from the Big White Salmon and Hood Rivers (inclusive) and any such fish originating from the Willamette River and its tributaries below Willamette Falls. Also, Coho salmon originate from 21 artificial propagation programs (Figure 39). The Lower Columbia River ESU of Coho salmon was listed as threatened under the ESA on June 28, 2005.

8.35.1 Life History

Lower Columbia River Coho salmon are typically categorized into early- and late-returning stocks. Early-returning (Type S) adult Coho salmon enter the Columbia River in mid-August and begin entering tributaries in early September, with peak spawning from mid-October to early November. Late-returning (Type N) Coho salmon pass through the lower Columbia from late September through December and enter tributaries from October through January. Most spawning occurs from November to January, but some occurs as late as March (LCFRB 2010).

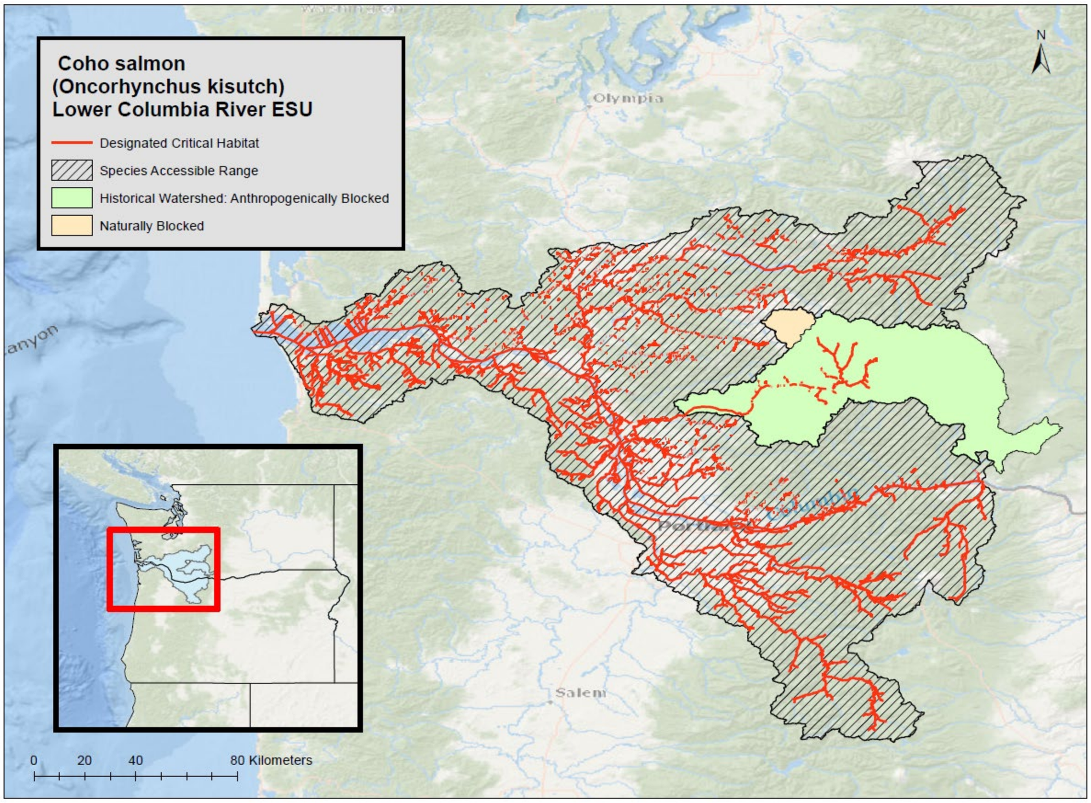

Figure 38. Geographic range and designated critical habitat of Coho salmon, Lower Columbia River ESU.

Coho salmon typically spawn in small to medium, low- to-moderate elevation streams from valley bottoms to stream headwaters. Coho salmon construct redds in gravel and small cobble substrate in pool tailouts, riffles, and glides, with sufficient flow depth for spawning activity (NMFS 2013c). Eggs incubate over late fall and winter for about 45 to 140 days, depending on water temperature, with longer incubation in colder water. Fry may thus emerge from early spring to early summer (ODFW 2010). Juveniles typically rear in freshwater for more than a year. After emergence, Coho salmon fry move to shallow, low-velocity rearing areas, primarily along the stream edges and inside channels. Juvenile Coho salmon favor pool habitat and often congregate in quiet backwaters, side channels, and small creeks with riparian cover and woody debris. Side-channel rearing areas are particularly critical for overwinter survival, which is a key regulator of freshwater productivity (LCFRB 2010).

Most juvenile Coho salmon migrate seaward as smolts in April to June, typically during their second year. Salmon that have stream-type life histories, such as Coho, typically do not linger for extended periods in the Columbia River estuary, but the estuary is a critical habitat used for feeding during the physiological adjustment to salt water. Juvenile Coho salmon are present in the Columbia River estuary from March to August. Columbia River Coho salmon typically range throughout the nearshore ocean over the continental shelf off the Oregon and Washington coasts. Early-returning (Type S) Coho salmon are typically found in ocean waters south of the Columbia River mouth. Late-returning (Type N) Coho salmon are typically found in ocean waters north of the Columbia River mouth. Most Coho salmon sexually mature at age three, except for a small percentage of males (called jacks) who return to natal waters at age two, after only five to seven months in the ocean (LCFRB 2010).

8.35.2 Population Dynamics

Washington tributaries indicate the presence of moderate numbers of Coho salmon, with total abundances in the hundreds to low thousands of fish. Oregon tributaries have abundances in the hundreds of fish. In the Western Cascade MPG, the Sandy and Clackamas Rivers were the only two populations identified in the original 1996 Status Review that appeared to be self-sustaining natural populations. Natural origin abundances in the Columbia Gorge MPG are low, with hatchery-origin fish contributing a large proportion of the total number of spawners, most notably in the Hood River. Current abundance estimates of the Lower Columbia River ESU of Coho salmon are presented in Table 36 and Table 37 below.

Table 35. Juvenile Abundance Estimates for the Lower Columbia River ESU of Coho Salmon (NMFS 2020).

Production	Life Stage	Abundance
Natural	Juvenile	651,378
Listed Hatchery Intact Adipose	Juvenile	287,056
Listed Hatchery Adipose Clipped	Juvenile	7,055,635

Table 36. Average abundance estimates for Lower Columbia River Chinook salmon natural- and hatchery-origin spawners (NMFS 2020).

Population Name	Years	Natural-origin Spawners	Hatchery-origin Spawners	% Hatchery Origin
Coastal Stratum – Fall run				
Youngs Bay	2012-2014	233	5,606	96.01%
Grays/Chinook	2010-2014	100	357	78.12%
Big Creek	2012-2014	32	1,510	97.92%
Elochoman/ Skamokowa	2010-2014	116	580	83.33%
Clatskanie	2012-2014	98	3,193	97.02%
Mill/Abernathy/Germany	2010-2014	92	805	89.74%

Population Name	Years	Natural-origin Spawners	Hatchery-origin Spawners	% Hatchery Origin
Cascade Stratum – Fall run				
Lower Cowlitz	2010-2013	723	196	21.33%
Upper Cowlitz	2010-2013	2,873	961	25.07%
Toutle	2010-2014	3,305	5,400	62.03%
Coweeman	2010-2014	385	963	71.44%
Kalama	2010-2014	803	8,892	91.72%
Lewis	2010-2014	2,178	943	30.21%
Washougal	2010-2014	192	116	37.66%
Clackamas	2012-2014	1,272	2,955	69.91%
Sandy	2012-2014	1,207	320	20.96%
Columbia Gorge Stratum – Fall run				
Lower Gorge	2003-2007	146	-	-
Upper Gorge	2010-2012	200	327	62.05%
White Salmon	2010-2014	829	246	22.88%
Cascade Stratum – Late fall run				
North Fork Lewis	2010-2014	12,330	0	0.00%
Cascade Stratum – Spring run				
Upper Cowlitz/Cispus	2010-2014	279	3,614	92.83%
Kalama	2011-2014	115	-	-
North Fork Lewis	2010-2014	217	0	0.00%
Sandy	2010-2014	1,731	1,470	45.92%
Gorge Stratum – Spring run				
White Salmon	2013-2014	13	140	91.50%
ESU Average		29,469	38,594	56.70%

Both the long- and short-term trend, and lambda for the natural origin (late-run) portion of the Clackamas River Coho salmon are negative but with large confidence intervals (Good et al.

2005). The short-term trend for the Sandy River population is close to 1, indicating a relatively stable population during the years 1990 to 2002 (Good et al. 2005). The long-term trend (1977 to 2002) for this same population shows that the population has been decreasing (trend=0.54); there is a 43 percent probability that the median population growth rate (lambda) was less than one. Long-term abundances in the Coast Range Cascade MPG were generally stable. Scappoose Creek is exhibiting a positive abundance trend. Clatskanie River Coho salmon population maintains moderate numbers of naturally produced spawners.

The spatial structure of some populations is constrained by migration barriers (such as tributary dams) and development in lowland areas. Low abundance, past stock transfers, other legacy hatchery effects, and ongoing hatchery straying may have reduced genetic diversity within and among Coho salmon populations (NWFSC 2015b). It is likely that hatchery effects have also decreased population productivity.

This ESU includes all naturally spawned populations of Coho salmon in the Columbia River and its tributaries in Washington and Oregon, from the mouth of the Columbia River up to and including the Big White Salmon and Hood Rivers, and includes the Willamette River to Willamette Falls, Oregon, as well as multiple artificial propagation programs. Most of the populations in the ESU contain a substantial number of hatchery-origin spawners. Myers et al (Myers et al. 2006) identified three MPGs (Coastal, Cascade, and Gorge), containing a total of 24 demographically independent populations (DIPs) in the Lower Columbia River Coho salmon ESU (NWFSC 2015b).

8.35.3 Status

Recovery efforts have likely improved the status of a number of Coho salmon DIPs, abundances are still at low levels and the majority of the DIPs remain at moderate or high risk. For the lower Columbia River region, land development and increasing human population pressures will likely continue to degrade habitat, especially in lowland areas. Although populations in this ESU have generally improved, especially in the 2013/14 and 2014/15 return years, recent poor ocean conditions suggest that population declines might occur in the upcoming return years. Regardless, this ESU is still considered to be at moderate risk (NWFSC 2015b).

8.35.4 Critical Habitat

Critical habitat for the Lower Columbia River Coho salmon ESU was designated on February 24, 2016 (81 FR 9252).

8.35.5 Recovery Goals

This species is included in the Lower Columbia River Recovery Plan (NMFS 2013b). Specific recovery goals are to improve all four viability parameters to the point that the Coast, Cascade, and Gorge strata achieve high probability of persistence. Protection of existing high functioning habitat and restoration of tributary habitat are noted needs, along with the reduction of hatchery and harvest impacts. Large improvements are needed in the persistence probability of most populations of this ESU.

8.36 Coho Salmon – Oregon Coast ESU

This ESU includes naturally spawned Coho salmon originating from coastal rivers south of the Columbia River and north of Cape Blanco, and also Coho salmon from one artificial propagation program: Cow Creek Hatchery Program (Figure 40). The Oregon Coast ESU of Coho salmon was listed as threatened under the ESA on August 10, 1998 (63 FR 42587). The listing was revisited and confirmed as threatened on June 20, 2011 (76 FR 35755).

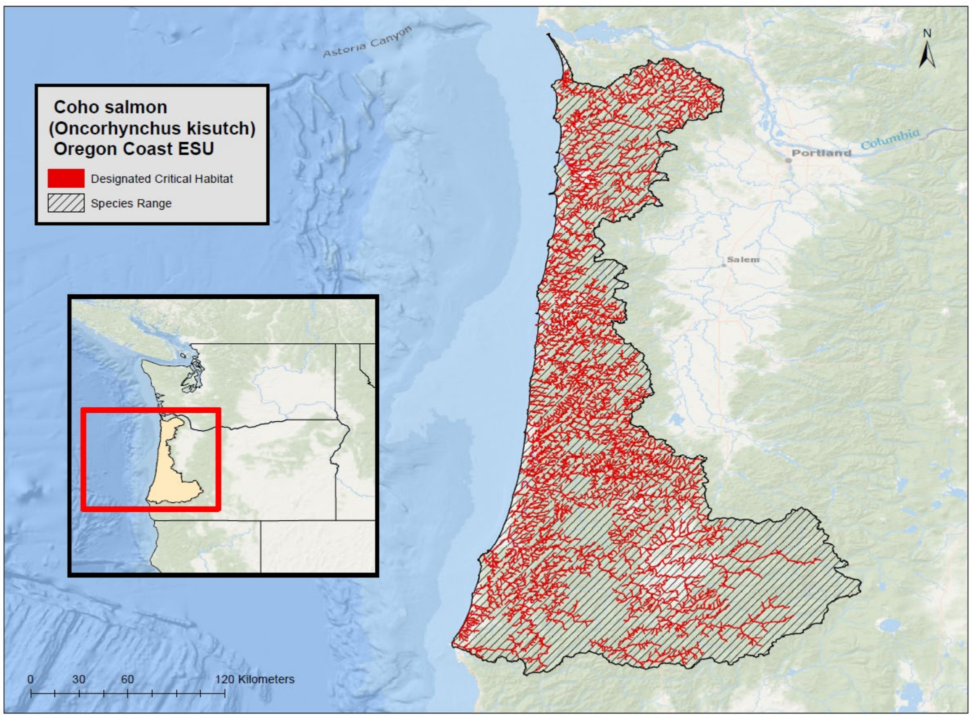

Figure 39. Geographic range and designated critical habitat of Coho salmon, Oregon coast ESU.

8.36.1 Life History

The anadromous life cycle of Coho salmon begins in their home stream where they emerge from eggs as alevins (a larval life stage dependent on food stored in a yolk sac). These very small fish require cool, slow moving freshwater streams with quiet areas such as backwater pools, beaver ponds, and side channels (Reeves et al. 1989) to survive and grow through summer and winter seasons. Current production of Coho salmon smolts in the Oregon Coast Coho salmon ESU is particularly limited by the availability of complex stream habitat that provides the shelter for overwintering juveniles during periods when flows are high, water temperatures are low, and food availability is limited (ODFW 2007).

The Oregon Coast Coho salmon follow a yearling-type life history strategy, with most juvenile Coho salmon migrating to the ocean as smolts in the spring, typically from as late as March into

June. Coho salmon smolts outmigrating from freshwater reaches may feed and grow in lower mainstem and estuarine habitats for a period of days or weeks before entering the nearshore ocean environment. The areas can serve as acclimation areas, allowing Coho salmon juveniles to adapt to saltwater. Research shows that substantial numbers of Coho fry may also emigrate downstream from natal streams into tidally influenced lower river wetlands and estuarine habitat (Chapman 1962; Koski 2009; Bass 2010).

Oregon Coast Coho salmon tend to make relatively short ocean migrations. Coho from this ESU are present in the ocean from northern California to southern British Columbia, and even fish from a given population can be widely dispersed in the coastal ocean, but the bulk of the ocean harvest of Coho salmon from this ESU are found off the Oregon coast. The majority of Coho salmon adults return to spawn as 3–year-old fish, having spent about 18 months in freshwater and 18 months in salt water (Sandercock 1991). The primary exceptions to this pattern are jacks, sexually mature males that return to freshwater to spawn after only five to seven months in the ocean.

8.36.2 Population Dynamics

Results from the most recent NWFSC review show that while Oregon Coast Coho salmon spawner abundance varies by time and population, the total abundance of spawners within the ESU has been generally increasing since 1999, with total abundance exceeding 280,000 spawners in three years between 2010 to 2015 (NWFSC 2015b).

Most independent populations in the ESU showed an overall increasing trend in abundance with synchronously high abundances in 2002 to 2003, 2009 to 2011, and 2014, and low abundances in 2007, 2009, and 2015. This synchrony suggests the overriding importance of marine survival to recruitment and escapement of Oregon Coast Coho salmon (NWFSC 2015b). When future conditions are taken into account, the Oregon Coast Coho salmon ESU, as a whole, is at moderate risk of extinction, but the recent risk trend is stable and improving (NWFSC 2015b). Current abundance estimates for natural and hatchery spawners as well as the expected number of outmigrants for the Oregon Coast ESU of Coho salmon are presented in Table 38 below. The hatchery production goal is 60,000 adipose-fin-clipped yearling Oregon Coast ESU Coho salmon (NMFS 2020).

Table 37. Average abundance estimates for the Oregon Coast ESU Coho salmon natural- and hatchery-origin spawners (NMFS 2020).

Population Name	Natural-origin Spawners[a]	Hatchery-origin Spawners[a]	% Hatchery Origin	Expected Number of Outmigrants[b]
North Coast Stratum				
Necanicum River	1,139	5	0.42%	80,063

Population Name	Natural-origin Spawners[a]	Hatchery-origin Spawners[a]	% Hatchery Origin	Expected Number of Outmigrants[b]
Nehalem River	7,073	11	0.16%	495,889
Tillamook Bay	4,771	19	0.39%	335,290
Nestucca River	2,320	2	0.09%	162,547
North Coast Dependents	602	3	0.49%	42,350
Mid-Coast Stratum				
Salmon River	924	9	0.98%	65,352
Siletz River	5,534	2	0.04%	387,545
Yaquina River	4,585	2	0.05%	321,141
Beaver Creek	1,634	1	0.09%	114,493
Alsea River	8,627	0	0.00%	603,904
Siuslaw River	12,994	0	0.00%	909,584
Mid Coast Dependents	1,190	7	0.56%	83,747
Lakes Stratum				
Siltcoos Lake	2,362	0	0.00%	165,333
Tahkenitch Lake	1,356	2	0.13%	95,077
Tenmile Lake	2,909	0	0.00%	203,660
Umpqua Stratum				
Lower Umpqua River	8,755	2	0.02%	612,987
Middle Umpqua River	3,080	0	0.00%	215,578
North Umpqua River	2,320	191	7.59%	175,760
South Umpqua River	3,683	299	7.52%	278,743
Mid-South Coast Stratum				
Coos River	6,320	0	0.00%	442,407
Coquille River	10,781	3	0.03%	754,870
Floras Creek	1,154	0	0.00%	80,785
Sixes River	200	0	0.00%	14,029

Population Name	Natural-origin Spawners[a]	Hatchery-origin Spawners[a]	% Hatchery Origin	Expected Number of Outmigrants[b]
Mid-South Coast Dependents	5	1	16.36%	428
ESU Average	94,320	559	0.59%	6,641,564

a Five-year geometric mean of post-fishery spawners (2013 to 2017).

b Expected number of outmigrants=Total spawners*50% proportion of females*2,000 eggs per female*7% survival rate from egg to outmigrant.

While the 2008 biological review team status review concluded that there was low certainty that ESU-level genetic diversity was sufficient for long-term sustainability in the ESU (Wainwright et al. 2008), a 2015 NWFSC review suggests this is an unlikely outcome. The observed upward trends in abundance and productivity and downward trends in hatchery influence make decreases in genetic or life history diversity or loss of dependent populations in recent years unlikely (NWFSC 2015b).

The geographic setting for the Oregon Coast Coho salmon ESU includes the Pacific Ocean and the freshwater habitat (rivers, streams, and lakes) along the Oregon Coast from the Necanicum River near Seaside on the north to the Sixes River near Port Orford on the south. The Oregon/Northern California Coasts Technical Recovery Team identified 56 historical populations that function collectively to form the Oregon Coast Coho salmon ESU. The team classified 21 of the populations as independent because they occur in basins with sufficient historical habitat to have persisted through several hundred years of normal variations in marine and freshwater conditions (NMFS 2016f).

8.36.3 Status

Findings by the NWFSC (2015b) and ODFW (2016) show many positive improvements to Oregon Coast Coho salmon in recent years, including positive long-term abundance trends and escapement. Results from the NWFSC's recent review show that while Oregon Coast Coho salmon spawner abundance varies by time and population, the total abundance of spawners within the ESU has generally increased since 1999, with total abundance exceeding 280,000 spawners in recent years. Overall, the NWFSC (2015b) found that increases in Oregon Coast Coho salmon ESU scores for persistence and sustainability clearly indicate that the biological status of the ESU is improving, due in large part to management decisions (reduced harvest and hatchery releases). It determined, however, that Oregon Coast Coho salmon abundance remains strongly correlated with marine survival rates.

8.36.4 Critical Habitat

NMFS published a final rule designating critical habitat for Oregon Coast Coho salmon on February 11, 2008 (70 FR 52488).

8.36.5 Recovery Goals

See the 2016 Recovery Plan for detailed descriptions of the recovery goals and delisting criteria (NMFS 2016f). In the simplest terms, NMFS will remove the Oregon Coast Coho salmon from federal protection under the ESA when we determine that:

- The species has achieved a biological status consistent with recovery—the best available information indicates it has sufficient abundance, population growth rate, population spatial structure, and diversity to indicate it has met the biological recovery goals.
- Factors that led to ESA listing have been reduced or eliminated to the point where federal protection under the ESA is no longer needed, and there is reasonable certainty that the relevant regulatory mechanisms are adequate to protect Oregon Coast Coho salmon sustainability.

8.37 Coho Salmon – Southern Oregon and Northern California Coasts ESU

This evolutionarily significant unit, or ESU, includes naturally spawned Coho salmon originating from coastal streams and rivers between Cape Blanco, Oregon, and Punta Gorda, California (Figure 43). Also, Coho salmon originate from three artificial propagation programs. The Southern Oregon/Northern California Coast (SONCC) ESU of Coho salmon was listed as threatened under the ESA on May 6, 1997 (62 FR 24588). The listing was revisited and confirmed as threatened on June 28, 2005.

8.37.1 Life History

Coho salmon is an anadromous fish species that generally exhibits a relatively simple three-year life cycle. Adults typically begin their freshwater spawning migration in the late summer and fall, spawn by mid-winter, and then die. The run and spawning times vary between and within populations. Depending on river temperatures, eggs incubate in redds for 1.5 to 4 months before hatching as alevins (a larval life stage dependent on food stored in a yolk sac). Once most of the yolk sac is absorbed, the 30 to 35 millimeter fish (then termed fry) begin emerging from the gravel in search of shallow stream margins for foraging and safety (Council 2004). Coho salmon fry typically transition to the juvenile stage by about mid-June when they are about 50 to 60 millimeters, and both stages are collectively referred to as young of the year. Juveniles develop vertical dark bands or parr marks, and begin partitioning available instream habitat through aggressive agonistic interactions with other juvenile fish (Quinn 2005). Juveniles rear in freshwater for up to 15 months, then migrate to the ocean as smolts in the spring. Coho salmon typically spend two growing seasons in the ocean before returning to their natal stream to spawn as 3 year-olds. Some precocious males, called jacks, return to spawn after only six months at sea (NMFS 2014a).

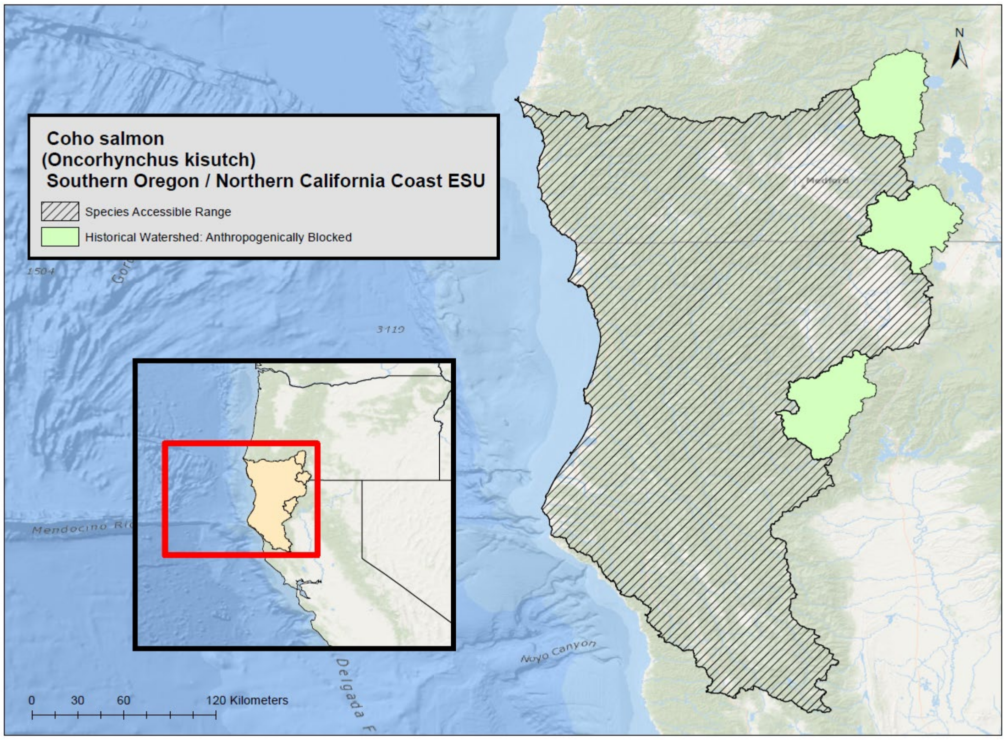

Figure 40. Geographic range of the Southern Oregon/Northern California ESU of Coho Salmon.

8.37.2 Population Dynamics

Although long-term data on abundance of SONCC Coho salmon are scarce, the best available data indicate that none of the seven diversity strata appear to support a single viable population, although all diversity strata are occupied (NMFS). Further, 24 out of 31 independent populations are at high risk of extinction and six are at moderate risk of extinction. Abundance estimates for adult SONCC ESU Coho salmon are presented in Table 39 below. Current average abundance estimates for juvenile SONCC ESU Coho salmon are 200,000 hatchery produced fish with clipped adipose fins, 575,000 hatchery produced fish with intact adipose fins, and 2,013,593 natural origin fish (NMFS 2020).

Table 38. Average abundance estimates of the natural-origin and hatchery-produced adult Southern Oregon/Northern California Coast ESU Coho salmon returning to the Rogue, Trinity, and Klamath rivers (NMFS 2020).

YEAR	Rogue River		Trinity River		Klamath River		
	Hatchery	Natural	Hatchery	Natural	Shasta River[a]	Scott River[a]	Salmon River
2008	158	414	3,851	944	30	62	
2009	518	2,566	2,439	542	9	81	
2010	753	3,073	2,863	658	44	927	

2011	1,156	3,917	9,009	1,178	62	355	
2012	1,423	5,440	8,662	1,761		201	
2013	1,999	11,210	11,177	4,097			
2014	829	2,409	8,712	917			
Average [b]	1,417	6,353	9,517	2,258	38	357	50 [c]

a Hatchery proportion unknown, but assumed to be low.

b 3-year average of most recent years of data.

c Annual returns of adults are likely less than 50 per year.

The extinction risk of an ESU depends upon the extinction risk of its constituent independent populations; because the population abundance of most independent populations are below their depensation threshold, the SONCC Coho salmon ESU is at high risk of extinction and is not viable (Williams et al. 2011). Estimates from the Rogue River with its four independent populations indicate a small but significant positive trend ($p = 0.01$) over the past 35 years and a non-significant negative trend ($p > 0.05$) over the past 12 years or four generations (NMFS 2016d). The decline in abundance from historical levels and the poor status of population viability criteria are the main factors behind the extinction risk of the ESU.

Williams et al. (2006b) designated 45 populations of Coho salmon in the SONCC Coho salmon ESU as dependent or independent based on their historical population size. Two populations are both small enough and isolated enough that they are only intermittently present (McElhany et al. 2000; Williams et al. 2006b; NMFS 2014a). These populations were further grouped into seven diversity strata based on the geographical arrangement of the populations and basin-scale genetic, environmental, and ecological characteristics.

8.37.3 Status

Though population-level estimates of abundance for most independent populations are lacking, the best available data indicate that none of the seven diversity strata appears to support a single viable population as defined by the SONCC Coho salmon technical recovery team's viability criteria (low extinction risk; Williams et al. (2008)). Further, 24 out of 31 independent populations are at high risk of extinction and six are at moderate risk of extinction. Based on the above discussion of the population viability parameters, and qualitative viability criteria presented in Williams et al. (2008), NMFS concludes that the SONCC Coho salmon ESU is currently not viable and is at high risk of extinction. The primary causes of the decline are likely long-standing human-caused conditions (e.g., harvest and habitat degradation), which exacerbated the impacts of adverse environmental conditions (e.g., drought and poor ocean conditions) (60 FR 38011; July 25, 1995).

8.37.4 Critical Habitat

NMFS designated critical habitat for the SONCC ESU of Coho salmon on May 5, 1999 (64 FR 24049).

8.37.5 Recovery Goals

A recovery plan is available for this species (NMFS 2014a). For recovery goals to be met at the ESU level, SONCC Coho salmon must demonstrate representation (genetic and life history diversity), redundancy (a sufficient number of populations to withstand catastrophic events), and connectivity (the dispersal capacity of populations to maintain long-term demographic and genetic processes).

9 ENVIRONMENTAL BASELINE

The "environmental baseline" refers to the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all Federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process. The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 C.F.R. §402.02).

The environmental baseline for this opinion includes the effects of several human activities that affect the survival and recovery of populations of ESA-listed marine mammals, sea turtles, and fish in the action area. Some human activities are ongoing and appear to continue to affect marine mammal, sea turtle, and fish populations in the action area for this consultation. Some of these activities, most notably commercial whaling, occurred extensively in the past and continue at low levels that no longer appear to significantly affect marine mammal populations, although the effects of past reductions in numbers persist today. The following discussion summarizes the impacts, which include climate change, oceanic temperature regimes, unusual mortality events, vessel activity, whale watching, fisheries (fisheries interactions, hatcheries, and aquaculture), pollution (marine debris, pesticides and contaminants, and hydrocarbons), aquatic nuisance species, anthropogenic sound (vessel sound and commercial shipping, seismic surveys, and marine construction), military activities, and scientific research activities.

9.1 Climate Change

There is a large and growing body of literature on past, present, and future impacts of global climate change, exacerbated and accelerated by human activities. Effects of climate change include sea level rise, increased frequency and magnitude of severe weather events, changes in air and water temperatures, and changes in precipitation patterns, all of which are likely to impact ESA resources. NOAA's climate information portal provides basic background information on these and other measured or anticipated climate change effects (see https://climate.gov). This section provides some examples of impacts to ESA-listed species and their habitats that have occurred or may occur as the result of climate change. We address climate change as it has affected ESA-listed species and continues to affect species, and we look to the foreseeable future to consider effects that we anticipate will occur as a result of ongoing activities. While the consideration of future impacts may also be suited to our cumulative effects analysis (Section 11), it is discussed here to provide a comprehensive analysis of the effects of climate change. While it is difficult to accurately predict the consequences of climate change to a particular species or habitat, a range of consequences are expected that are likely to change the status of the species and the condition of their habitats both within and outside of the action area.

In order to evaluate the implications of different climate outcomes and associated impacts throughout the 21st century, many factors have to be considered. The amount of future greenhouse gas emissions is a key variable. Developments in technology, changes in energy generation and land use, global and regional economic circumstances, and population growth must also be considered.

A set of four scenarios was developed by the Intergovernmental Panel on Climate Change (IPCC) to ensure that starting conditions, historical data, and projections are employed consistently across the various branches of climate science. The scenarios are referred to as representative concentration pathways (RCPs), which capture a range of potential greenhouse gas emissions pathways and associated atmospheric concentration levels through 2100 (IPCC 2014a). The RCP scenarios drive climate model projections for temperature, precipitation, sea level, and other variables: RCP2.6 is a stringent mitigation scenario; RCP2.5 and RCP6.0 are intermediate scenarios; and RCP8.5 is a scenario with no mitigation or reduction in the use of fossil fuels. The IPCC future global climate predictions (2014 and 2018) and national and regional climate predictions included in the Fourth National Climate Assessment for U.S. states and territories (2018) use the RCP scenarios.

The increase of global mean surface temperature change by 2100 is projected to be 0.3 to 1.7 degrees Celsius under RCP2.6, 1.1 to 2.6 degrees Celsius under RCP4.5, 1.4 to 3.1 degrees Celsius under RCP6.0, and 2.6 to 4.8 degrees Celsius under RCP8.5 with the Arctic region warming more rapidly than the global mean under all scenarios (IPCC 2014a). The Paris Agreement (an agreement within the United Nations Framework Convention on Climate Change, dealing with greenhouse-gas-emissions mitigation, adaptation, and finance, signed in 2016) aims to limit the future rise in global average temperature to 2 degrees Celsius, but the observed acceleration in carbon emissions over the last 15 to 20 years, even with a lower trend in 2016, has been consistent with higher future scenarios such as RCP8.5 (Hayhoe et al. 2018).

The globally-averaged combined land and ocean surface temperature data, as calculated by a linear trend, show a warming of approximately 1 degrees Celsius from 1901 through 2016 (Hayhoe et al. 2018). The *IPCC Special Report on the Impacts of Global Warming* (2018) (IPCC

2018) noted that human-induced warming reached temperatures between 0.8 and 1.2 degrees Celsius above pre-industrial levels in 2017, likely increasing between 0.1 and 0.3 degrees Celsius per decade. Warming greater than the global average has already been experienced in many regions and seasons, with most land regions experiencing greater warming than over the ocean (Allen et al. 2018). Annual average temperatures have increased by 1.8 degrees Celsius across the contiguous U.S. since the beginning of the 20th century with Alaska warming faster than any other state and twice as fast as the global average since the mid-20th century (Jay et al. 2018). Global warming has led to more frequent heatwaves in most land regions and an increase in the frequency and duration of marine heatwaves (IPCC 2018). Average global warming up to 1.5 degrees Celsius as compared to pre-industrial levels is expected to lead to regional changes in extreme temperatures, and increases in the frequency and intensity of precipitation and drought (IPCC 2018).

Consequences of climate change include increased ocean stratification, decreased sea-ice extent, altered patterns of ocean circulation, and decreased ocean oxygen levels (Doney et al. 2012). Since the early 1980s, the annual minimum sea ice extent (observed in September each year) in the Arctic Ocean has decreased at a rate of 11 to 16 percent per decade (Jay et al. 2018). Further, ocean acidity has increased by 26 percent since the beginning of the industrial era (IPCC 2014a) and this rise has been linked to climate change. Climate change is also expected to increase the frequency of extreme weather and climate events including, but not limited to, cyclones, tropical storms, heat waves, and droughts (IPCC 2014a).

Changes in the marine ecosystem caused by global climate change (e.g., ocean acidification, salinity, oceanic currents, dissolved oxygen levels, nutrient distribution) could influence the distribution and abundance of lower trophic levels (e.g., phytoplankton, zooplankton, submerged aquatic vegetation, crustaceans, mollusks, forage fish), ultimately affecting primary foraging areas of ESA-listed species including cetaceans, sea turtles, and fish – regardless of the ocean basin. Marine species ranges are expected to shift as they align their distributions to match their physiological tolerances under changing environmental conditions (Doney et al. 2012). We expect the same changes to occur with ESA-listed species within the action area.

Climate change has the potential to impact species abundance, geographic distribution, migration patterns, and susceptibility to disease and contaminants, as well as the timing of seasonal activities and community composition and structure (MacLeod et al. 2005; Robinson et al. 2005; Kintisch 2006; Learmonth et al. 2006a; McMahon and Hays 2006; Evans and Bjørge 2013; IPCC 2014a). Hazen et al. (2012) examined top predator distribution and diversity in the Pacific Ocean in light of rising sea surface temperatures using a database of electronic tags and output from a global climate model. They predicted up to a 35 percent change in core habitat area for some key marine predators in the Pacific Ocean, with some species predicted to experience gains in available core habitat and some predicted to experience losses. Notably, leatherback turtles were predicted to gain core habitat area, whereas blue whales were predicted to experience losses in available core habitat. (McMahon and Hays 2006) predicted increased ocean temperatures will expand the distribution of leatherback turtles into more northern latitudes. The authors noted this is already occurring in the Atlantic Ocean. (Macleod 2009) estimated, based upon expected shifts in water temperature, 88 percent of cetaceans will be affected by climate change; with 47 percent predicted to experience unfavorable conditions (e.g., range contraction). (Willis-Norton et al. 2015) acknowledged there will be both habitat loss and gain, but overall climate change could result in a 15 percent loss of core pelagic habitat for leatherback turtles in the eastern South Pacific Ocean.

Though predicting the precise consequences of climate change on highly mobile marine species is difficult (Simmonds and Isaac 2007a), research has indicated that the foraging habits of Guadalupe fur seals change during warming events in El Niño years, probably linked to a decline in primary productivity is coastal areas, associated with increased sea surface temperatures, causing them to forage further offshore. Observed individuals exhibited diminished body condition, especially pups (Elorriaga-Verplancken et al. 2016). The circumstances in this example are related to El Niño Southern Oscillation event, and not climate change precisely, but it does provide insight into how Guadalupe fur seals may be affected as oceans warm under various climate change scenarios.

Similarly, climate-related changes in important prey species populations are likely to affect predator populations. Climate-mediated changes in the distribution and abundance of keystone prey species like krill and in cephalopod populations worldwide will likely affect marine mammal populations as they re-distribute throughout the world's oceans in search of prey. Blue whales, as predators that specialize in eating krill, seem likely to change their distribution in response to changes in the distribution of krill (Payne et al. 1990); if they did not change their distribution or could not find the biomass of krill necessary to sustain their population numbers, their populations seem likely to experience declines similar to those observed in other krill predators, which would cause dramatic declines in their population sizes or would increase the year-to-year variation in population size; either of these outcomes would dramatically increase the extinction probabilities of these whales. Pecl and Jackson (2008) predicted climate change will likely result in squid that hatch out smaller and earlier, undergo faster growth over shorter life-spans, and mature younger at a smaller size. This could have negative consequences for species such as sperm whales and Guadalupe fur seals, whose diet is primarily squid and cephalopods. Sperm whales and Guadalupe fur seals, whose diets can be dominated by cephalopods, would have to re-distribute following changes in the distribution and abundance of their prey. This statement assumes that projected changes in global climate would only affect the distribution of cephalopod populations, but would not reduce the number or density of cephalopod populations. If, however, cephalopod populations collapse or decline dramatically, sperm whale populations are likely to collapse or decline dramatically as well.

For leatherback sea turtles, Guadalupe fur seals, and ESA-listed whales which undergo long migrations, if either prey availability or habitat suitability is disrupted by changing ocean temperatures, regimes, the timing of migration can change or negatively impact population sustainability (Simmonds and Eliott 2009). Southern Resident killer whales might shift their distribution in response to climate-related changes in their salmon prey (NMFS 2019a). Climatic conditions affect salmonid abundance, productivity, spatial structure, and diversity through direct and indirect impacts at all life stages (e.g., Independent Science Advisory Board 2007; Lindley et al. 2007; Crozier et al. 2008; Moyle et al. 2013; Wainwright and Weitkamp 2013).

Pacific salmonids could be affected by rising water temperatures in streams, impacting habitat suitability and salmon growth, development, smoltification, and egg development (Crozier et al. 2008). Green sturgeon could be subjected to physiological and cellular stresses caused by changes in water temperature and salinity, possibly leading to fitness consequences (Sardella et al. 2008; Sardella and Kültz 2014).

Studies examining the effects of long-term climate change to salmon populations have identified a number of common mechanisms by which climate variation is likely to influence salmon sustainability. These include direct effects of temperature such as mortality from heat stress, changes in growth and development rates, and disease resistance (NMFS 2019a). Changes in the flow regime (especially flooding and low flow events) also affect survival and behavior. Expected behavioral responses include shifts in seasonal timing of important life history events, such as the adult migration, spawn timing, fry emergence timing, and the juvenile migration. Indirect effects on salmon mortality, growth rates and movement behavior are also expected to follow from changes in the freshwater habitat structure and the invertebrate and vertebrate community, which governs food supply and predation risk (Petersen and Kitchell 2001; Independent Science Advisory Board 2007; Crozier et al. 2008).

Crozier et al. (2019) conducted an extensive analysis on ESA-listed salmonid and steelhead vulnerability to climate change. Nearly all listed populations faced high exposures to projected increases in stream temperature, sea surface temperature, and ocean acidification. The highest vulnerability scores for extrinsic effects (anthropogenic stressors) occurred in interior and southern regions where climate is expected to change the most. Populations ranked as the most vulnerable to climate change overall were California Central Valley Chinook salmon, California and southern Oregon Coho salmon, Snake River Basin sockeye salmon, and Columbia and Willamette River spring-run Chinook salmon (Crozier et al. 2019).

In the marine ecosystem, salmon may be affected by warmer water temperatures, increased stratification of the water column, intensity and timing changes of coastal upwelling, loss of coastal habitat due to sea level rise, ocean acidification, and changes in water quality and freshwater inputs (Independent Science Advisory Board 2007; Mauger et al. 2015). Salmon marine migration patterns could be affected by climate-induced contraction of thermally suitable habitat. Abdul-Aziz et al. (2011) modeled changes in summer thermal ranges in the open ocean for Pacific salmon under multiple IPCC warming scenarios. For chum salmon, pink, Coho salmon, sockeye salmon and steelhead, they predicted contractions in suitable marine habitat of 30-50% by the 2080s, with an even larger contraction (86-88%) for Chinook salmon under the medium and high emissions scenarios. Northward range shifts are a climate response expected in many marine species, including salmon (Cheung et al. 2015). However, salmon populations are strongly differentiated in the northward extent of their ocean migration, and hence will likely respond individualistically to widespread changes in sea surface temperature (NMFS 2019a). In a meta-analytical review of multiple peer-reviewed papers on green sturgeon, Rodgers et al. (2019) reported that elevated temperatures significantly reduce growth and hatching success and increase the incidence of larval deformities.

The adaptive capacity of threatened and endangered salmonid species is depressed due to reductions in population size, habitat quantity and diversity, and loss of behavioral and genetic variation (NMFS 2019a). Without these natural sources of resilience, systematic changes in local and regional climatic conditions due to anthropogenic global climate change are more likely to reduce long-term viability and sustainability of salmon populations, although the character and magnitude of these effects will likely vary within and among ESUs (NMFS 2019a). Muñoz et al. (2015) reported finding a constraint on the upper limit of thermal tolerance in the Quinsam River juvenile Chinook salmon population. Although fish in this study exhibited both physiological and genetic capacities to increase their thermal tolerance in response to rising temperatures, results suggest that Pacific salmon populations are physiologically susceptible to the projected increases in river temperatures associated with climate change. Based on the observed constraint on thermal tolerance and present-day river temperatures, Muñoz et al. (2015) predict a 17 percent chance of catastrophic loss in the studied population by 2100 based on the average warming projection, with this chance increasing to 98 percent in the maximum warming scenario.

Anthropogenic climate change is also linked to food web and salinity fluctuations in estuarine environments as a result of sea level rise and seawater intrusion coupled with smaller snowpack and lower spring freshwater flows. Larger and less stable salinity regimes coupled with altered food web dynamics may have direct physiological consequences for green sturgeon juveniles in addition to indirectly affecting the quality and quantity of their prey organisms (Haller et al. 2015). In a meta-analytical review of multiple peer-reviewed papers on green sturgeon, Rodgers et al. (2019) reported that, on average, exposure to elevated salinity levels negatively affected growth, and that plasma osmolality and muscle moisture are significantly increased in response to salinity exposure. Haller et al. (2015) studied the effect of nutritional status on the osmoregulation of green sturgeon. The largest disturbances caused by feed restriction were observed at the highest salinity treatments across all feeding regimes, and the interaction between feed restriction and acute salinity exposure at the highest salinity treatment resulted in high mortality rates during the first 72 hours of salinity exposure (Haller et al. 2015). Sardella et al. (2014) studied the physiological responses of green sturgeon to potential global climate change stressors. They found that while sturgeon can acclimate to changes in salinity, salinity fluctuations resulted in substantial cellular stress.

Effects of ocean acidification on ESA-listed fish most likely occur through ecological mechanisms mediated by changes to the food web (Busch et al. 2013; Crozier et al. 2019). Taxa directly affected by declining marine pH include invertebrates such as pteropods, crabs, and krill. Physiological effects of acidification may also impair olfaction, which could hinder salmonid homing ability, along with other developmental effects (Crozier et al. 2019). Climate change impacts on ocean conditions were classified as the most serious threat to the Southern DPS of eulachon by NOAA's Biological Review Team (Gustafson et al. 2010; NMFS 2017c).

This review provides some examples of impacts to ESA-listed species and their habitats that may occur as the result of climate change. While it is difficult to accurately predict the consequences of climate change to a particular species or habitat, a range of consequences are expected that are likely to change the status of the species and the condition of their habitats.

9.2 Oceanic Temperature Regimes

Oceanographic conditions in the Pacific Ocean can be altered due to periodic shifts in atmospheric patterns caused by the Southern oscillation in the Pacific Ocean, which leads to El Niño and La Niña events and the Pacific decadal oscillation. These climatic events can alter habitat conditions and prey distribution for ESA-listed species in the action areas (Beamish 1993; Mantua et al. 1997; Hare and Mantua 2001; Benson and Trites 2002; Stabeno et al. 2004; Mundy and Cooney 2005).

The Pacific decadal oscillation is the leading mode of variability in the North Pacific Ocean and operates over longer periods than either El Niño or La Niña/Southern Oscillation events and is capable of altering sea surface temperature, surface winds, and sea level pressure (Mantua and Hare 2002; Stabeno et al. 2004). During positive Pacific decadal oscillations, the northeastern Pacific experiences above average sea surface temperatures while the central and western Pacific Ocean undergoes below-normal sea surface temperatures (Royer 2005). Warm Pacific decadal oscillation regimes, as occurs in El Niño events, tends to decrease productivity along the U.S. west coast, as upwelling typically diminishes (Hare et al. 1999; Childers et al. 2005). Recent sampling of oceanographic conditions just south of Seward, Alaska has revealed anomalously cold conditions in the Gulf of Alaska from 2006 through 2009, suggesting a shift to a colder Pacific decadal oscillation phase. More research needs to be done to determine if the region is indeed shifting to a colder Pacific decadal oscillation phase in addition to what effects these phase shifts have on the dynamics of prey populations important to ESA-listed cetaceans throughout the Pacific action area. A shift to a colder decadal oscillation phase would be expected to impact prey populations, although the magnitude of this effect is uncertain.

In addition to period variation in weather and climate patterns that affect oceanographic conditions in the action area, longer-term trends in climate change and/or variability also have the potential to alter habitat conditions suitable for ESA-listed species in the action area on a much longer time scale. The average global surface temperature rose by 0.85ºC from 1880 to 2012, and it continues to rise at an accelerating pace (IPCC 2014b); the 15 warmest years on record since 1880 have occurred in the 21st century (NCEI 2016). 2016 is the warmest year on record, followed by 2020 as the second warmest. The warmest year on record for global sea surface temperature was also 2016, and 2020 as the eighth warmest[4].

[4] https://www.ncei.noaa.gov/news/global-climate-202012 (Accessed 3/8/2021)

Possible effects of this trend in climate change and/or variability for ESA-listed marine species in the action area include the alteration of community composition and structure, changes to migration patterns or community structure, changes to species abundance, increased susceptibility to disease and contaminants, altered timing of breeding and nesting, and increased stress levels (MacLeod et al. 2005; Robinson et al. 2005; Kintisch 2006; Learmonth et al. 2006b; McMahon and Hays 2006). Climate change can influence reproductive success by altering prey availability, as evidenced by the low success of Northern elephant seals (*Mirounga angustirostris*) during El Niño periods (McMahon and Burton 2005) as well as data suggesting that sperm whale females have lower rates of conception following periods of unusually warm sear surface temperature (Whitehead et al. 1997). However, gaps in information and the complexity of climatic interactions complicate the ability to predict the effects that climate change and/or variability may have to these species from year to year in the action area (Kintisch 2006; Simmonds and Isaac 2007b).

9.3 Unusual Mortality Events

Under the MMPA, an unusual mortality event (UME) is defined as "a stranding that is unexpected; involves a significant die-off of any marine mammal population; and demands immediate response." In the past, an UME was declared for fin and humpback whales in British Columbia (including Vancouver Island) and Gulf of Alaska, from April 23, 2015 to April 16, 2016, where 52 individuals were found dead.[5] The investigation did not determine a cause for the unusual mortality event, although ecological factors like the 2015 El Nino event, the warm water blob, and the Pacific Coast Domoic Acid Bloom were contributing factors. Only one unusual mortality event[6] is active for ESA-listed marine mammals within the action area: Guadalupe fur seals. An UME was declared for Guadalupe fur seals beginning in January 2015, and continuing to the present (2015 to 2020)[7]. The UME was declared due to the increased stranding of Guadalupe fur seals in California, and was expanded to include Oregon and Washington due to the elevated number of strandings there. Strandings in Oregon and Washington have been well above typical numbers since 2015 (Figure 44).

[5] https://www.fisheries.noaa.gov/national/marine-life-distress/2015-2016-large-whale-unusual-mortality-event-western-gulf-alaska (Accesed 3/8/2021).
[6] There is an active UME for gray whales, but because we have concluded that gray whales are not likely to be adversely affected by the proposed action, are not discussing that UME here.
[7] https://www.fisheries.noaa.gov/national/marine-life-distress/2015-2019-guadalupe-fur-seal-unusual-mortality-event-california (Accessed 3/8/2021).

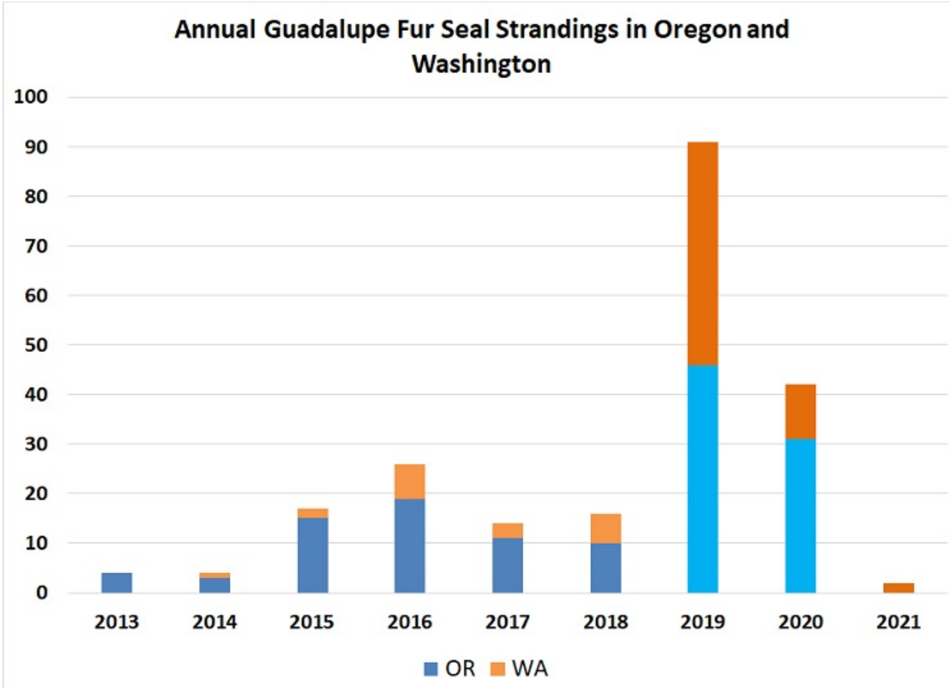

Figure 41. Guadalupe fur seal annual strandings in Oregon and Washington, 2013 to 2021 (as of 3/8/2021).

Guadalupe fur seal strandings generally peak in April through June each year. Stranded individuals were mostly weaned pups and juveniles, aged one to two years old. Most stranded individuals showed signs of malnutrition and had secondary bacterial and parasitic infections. As the UME is currently on going, we expect Guadalupe fur seals to continue to be impacted.

9.4 Vessel Activity

Vessels have the potential to affect animals through strikes, sound, and disturbance associated with their physical presence. Responses to vessel interactions include interruption of vital behaviors and social groups, separation of mothers and young, and abandonment of resting areas (Mann et al. 2000; Samuels et al. 2000; Boren et al. 2001; Constantine 2001; Nowacek 2001). Whales have been documented to exhibit avoidance behavior near vessels. A blue whale aborted its ascent when it was 57.5 meters from the vessel, and stayed underwater for three minutes beyond its projected surfacing time (Szesciorka et al. 2019). A study focusing on Southern Resident killer whales showed that individuals altered their foraging behavior when near vessels. When vessels were at an average distance of less than 400 yards (366 meters), individuals made fewer dives involving prey capture, and spent less time in these dives. The researchers found differences in response between the sexes, with female Southern Resident killer whales making fewer dives than males when vessels were less than 400 yards away (Holt et al. 2021).

Overall, the action area sees a great deal of vessel activity, from cargo and commercial shipping, to recreational vessels, cruise ships, and whale watching vessels. Washington and Oregon have several major ports in their state waters, with Seattle and Tacoma handling the most tonnage annually (Table 40).

Table 39. Major ports in Washington and Oregon with annual tonnage (NOAA 2020b; NOAA 2020a).

Port Name	Tonnage (year)
Kalama, WA	15,370,094
Coos Bay, OR	2,088,259
Tacoma, WA	25,711,848
Seattle, WA	24,204,009
Longview, WA	15,370,094
Anacortes, WA	10,682,558
Vancouver, WA	9,359,385
Grays Harbor, WA	2,307,901
Everett, WA	1,499,583
Olympia, WA	1,271,809

Ports in Canada contribute to vessel traffic within the action area. There are 135 public and private ports in British Columbia, with the Port of Vancouver, Fraser Port, and the Port of Prince Rupert accounting for more than 95 percent of the international trade moving through the British Columbian port system (Transportation 2005). The second largest port in British Columbia, the Port of Prince Rupert, is in northern British Columbia, and not within the action area. The Port of Vancouver and Fraser Port (the first and third largest ports) merged in 2008 and are overseen by the Vancouver Fraser Port Authority. Cargo from the Fraser Port is transmitted through the Port of Vancouver, and those statistics are combined. The amount of metric tons of cargo handled through the port increased every year from 2015 to 2018, the years for which complete data is available (Table 41).

Table 40. Annual summary of metric tons of cargo handled by the Port of Vancouver, 2015 to 2019 (Vancouver 2017; Vancouver 2018b; Vancouver 2019a).

Year	Metric Tons
2015	138,084,076
2016	135,537,413
2017	142,067,550

Year	Metric Tons
2018	147,093,499
2019	144, 225,630

In addition to shipping commerce, cruise ships constitute a large amount of shipping traffic in the within the action area. In 2019, 288 cruise ships entered the Port of Vancouver, with over a million passengers embarking and disembarking. This is about a 20 percent increase from 2018, which saw 241 vessels, and 889,162 passengers. Cruise ship activity was greatest in May through September (Vancouver 2019b). The number of cruise ship passengers into and out of the Port of Vancouver has steadily increased since 2015, which had around 805,415 passengers that year (Vancouver 2017). The Port of Seattle had over 1.2 million cruise ship passengers in 2019, with 213 ports of call, up from 120,000 passengers in 2000 (Seattle 2019). Although not a cruise ship hub like Seattle or Vancouver, there is still vessel traffic to and from the Port of Newport, in coastal Oregon, which supports a large commercial fishing fleet, a recreational vessel marina, and serves as the homeport for NOAA's Marine Operation Cetner, including six NOAA research and survey ships.

In addition, whale watching, which is discussed below, is a large industry affecting whales in the action area, especially Southern Resident killer whales, and resulting in vessel activity.

9.4.1 Whale Watching

Whale watching, a profitable and rapidly growing business with more than nine million participants in 80 countries and territories, may increase vessel disturbance and negatively affect whales (Hoyt 2001). Whale watching expeditions operate from the Oregon coast, primarily seeing gray whales and humpback whales.[8] Whale watching in Washington State and British Columbia are largely focused in the Salish Sea and Puget Sound, targeting killer whales, although whale-watching expeditions from Vancouver and Victoria target other species, like humpback whales. Several studies have examined the effects of whale watching on marine mammals, and investigators have observed a variety of short-term responses from animals, ranging from no apparent response to changes in vocalizations, duration of time spend at the surface, swimming speed, swimming angle or direction, respiration rate, dive time, feeding behavior, and social behavior (NMFS 2008d). Responses appear to be dependent on factors such as vessel proximity, speed, and direction, as well as the number of vessels in the vicinity (see 76 FR 20870 for a review).

Whale watching activities are particularly relevant for Southern Resident killer whales in the action area because, due to their popularity and local abundance in the area, Southern Resident killer whales are the primary target of these operations. Pods of Southern Resident killer whales

[8] https://oregonstateparks.org/index.cfm?do=thingstodo.dsp_whalewatching (Accessed 10/22/2020).

can also attract a large number of recreational vessels. In a study, the maximum number of vessels following a single pod of Southern Resident killer whales ranged from 72 to 120 annually; the majority was recreational vessels (Lachmuth et al. 2011). The Whale Museum estimates that more than half a million people annually go whale watching in British Columbia and Washington, making up a $40 to 50 million dollar industry (Seely et al. 2017). In addition, private floatplanes, helicopters, and small aircraft regularly take advantage of whale watching opportunities (MMMP 2002); the growing number of kayakers viewing Southern Resident killer whales and closely approaching pods in the central Salish Sea is an emerging concern for managers (Seely et al. 2017).

This increase and intensity in whale watching has resulted in exposure of Southern Resident killer whales to vessel traffic and sound. Whale watching activities can affect Southern Resident killer whales by disturbing their normal activities (like feeding or swimming) or displacing them (Lusseau et al. 2009a). In 2005, a commercial whale watching vessel struck a Southern Resident killer whale, inflicting a minor injury, which subsequently healed (NMFS 2008d). Although mechanisms are in place to regulate the industry, concerns remain over persistent exposure to vessel noise, proximity to whales, which can cause behavioral changes, stress, or potentially the loss of habitat (Kruse 1991; Kriete 2002; Williams et al. 2002; Foote et al. 2004; Bain et al. 2006; NMFS 2008d; Wiley et al. 2008; Noren et al. 2009a). As Southern Resident killer whales are normally exposed to high levels of whale watching, and vessel traffic in general, engine exhaust has been assessed as a possible threat and may contribute to health effects (Lachmuth et al. 2011).Other targeted whale species can be subjected to the same stressors from whale watching.

9.4.2 Vessel Strike

Vessel strikes are considered a serious and widespread threat to ESA-listed marine mammals (especially large whales) and sea turtles. Generally, the most well documented "marine road" interaction is with large whales (Pirotta et al. 2019). This threat is increasing as commercial shipping lanes cross important breeding and feeding habitats and as whale populations recover and populate new areas or areas where they were previously extirpated (Swingle et al. 1993; Wiley et al. 1995). As vessels continue to become faster and more widespread, an increase in vessel interactions with cetaceans is to be expected. Vessel traffic within the action area can come from both private (e.g., commercial, recreational) and federal vessel (e.g., military, research), but traffic that is most likely to result in vessel strikes comes from commercial shipping. All sizes and types of vessels can hit whales, but most lethal and severe injuries are caused by vessels 80 meters (262.5 feet) or longer (Laist et al. 2001). For whales, studies show that the probability of fatal injuries from vessel strikes increases as vessels operate at speeds above 26 kilometers per hour (14 knots) (Laist et al. 2001). Evidence suggests that not all whales killed because of vessel strike are detected, particularly in offshore waters. Some detected carcasses are never recovered while those that are recovered may be in advanced stages of decomposition that preclude a definitive cause of death determination (Glass et al. 2010). The vast majority of commercial vessel strike mortalities of cetaceans are likely undetected and unreported, as most are likely never reported. Most animals killed by vessel strike likely end up sinking rather than washing up on shore (Cassoff 2011). Kraus et al. (2005) estimated that 17 percent of vessel strikes are actually detected. Therefore, it is likely that the number of documented cetacean mortalities related to vessel strikes is much lower than the actual number of moralities associated with vessel strikes, especially for less buoyant species such as blue, humpback, and fin whales (Rockwood et al. 2017). Rockwood et al. (2017) modeled vessel strike mortalities of blue, humpback, and fin whales off the U.S. West Coast (California, Oregon, and Washington including the action area) using carcass recovery rates of five and 17 percent. The authors conservatively estimated that vessel strike mortality might be as high as 7.8, 2.0, and 2.7 times the recommended human-caused mortality limit for blue, humpback, and fin whales in this area, respectively.

The potential lethal effects of vessel strikes are particularly profound on species with low abundance. However, all whale species have the potential to be affected by vessel strikes. Of 11 species of cetaceans known to be threatened by vessel strikes in the northern hemisphere, fin whales are the mostly commonly struck species, but North Atlantic right, gray, humpback, and sperm whales are also struck (Laist et al. 2001; Vanderlaan and Taggart 2007). The latest five-year average mortalities and serious injuries related to vessel strikes for the ESA-listed cetacean stocks within U.S. waters likely to be found in the action area are and experience adverse effects as a result of the proposed action are given in Table 42 below (Carretta 2019b). These data represent only known mortalities and serious injuries. It is probable that more undocumented mortalities and serious injuries within the action area have likely occurred.

Williams and O'Hara (2010) found high risk areas in British Columbia for vessel strike for humpback, fin and killer whales included narrow straits and passageways, particularly Hecate Strait, Dixon entrance, the southeastern end of the Queen Charlotte Islands, and Queen Charlotte Sound.

Table 41. Five-year annual average mortalities and serious injuries related to vessel strikes for Endangered Species Act-listed Pacific stock marine mammals within the action area.

Species	Observed	Estimated
Blue Whale	0.2	18
Fin Whale	1.6	43
Humpback Whale – Multiple ESA-listed DPSs	2.1	22
Sei Whale	0.2	N/A
Sperm Whale	0	0

Guadalupe Fur Seal	0	0

DPS=Distinct Population Segment

Due to their small population size, Southern Resident killer whales are especially vulnerable to vessel strike, and there have been cases of vessel strike in the population. J-34, a young adult male, was found dead in Georgia Strait in the fall of 2016, with blunt force trauma injuries, consistent with vessel strike. In 2005, a Southern Resident was struck by a vessel, with minor injuries. In another case in 2006, L-98, a male, was killed by a vessel interaction, after notably becoming habituated to vessel presence in Nootka Sound (Carretta et al. 2019).

There have been various measures instituted to reduce risk of vessel strike to large whales in the action area. For example, in Burrard Inlet, the pathway into the Port of Vancouver, a voluntary 15-knot speed restriction was instituted in 2018, applying to tier two vessels (e.g., recreational powerboats, fishing boats, sailboats, tugs, ferries, whale-watching boats). Deep sea vessels (e.g. boat) already adhere to a 10-knot speed restriction while transiting the First Narrows Traffic Control Zone (Vancouver 2018a). Speed restrictions also reduce the amount of sound created by the vessel. (Joy et al. 2019) showed that when commercial vessels reduced their speed to 11 knots while transiting through Georgia Strait reduced underwater noise, potentially beneficial to Southern Resident killer whales (see Section 9.9.3 for a more detailed discussion on anthropogenic sound in the action area). Voluntary vessel slowdowns in Haro Strait (to 15 knots and 12.5 knots, depending on vessel size), led to a simulated 15 percent reduction in “lost” foraging time for Southern Resident killer whales (Trounce et al. 2019).

Vessel strikes are a poorly-studied threat to sea turtles, but have the potential to be highly significant given that they can result in serious injury and mortality (Work et al. 2010a). All sea turtles must surface to breathe and several species are known to bask at the sea surface for long periods. Although sea turtles can move somewhat rapidly, they apparently are not adept at avoiding vessels that are moving at more than 4 kilometers per hour (2.6 knots); most vessels move far faster than this in open water (Hazel and Gyuris 2006; Hazel et al. 2007; Work et al. 2010a). Both live and dead sea turtles are often found with deep cuts and fractures indicative of a collision with a vessel hull or propeller (Hazel et al. 2007). Hazel et al. (2007) suggests that green turtles may use auditory clues to react to approaching vessels rather than visual cues, making them more susceptible to strike or vessel speed increases. Although it is possible to occur, data on vessel strikes of leatherback sea turtles in the action area is lacking.

Vessel strike are a less pronounced threat to fishes in the action area, as fish are mostly expected to be able to sense and maneuver away from vessels. However, sturgeon have been known to be struck and killed by vessels. Demetras et al. (2020) documented an adult male white sturgeon mortality from vessel strike in the San Francisco Bay; the location of this event is notable in that the threatened southern DPS green sturgeon uses the same area, and is thus likely facing similar threats from vessels. We are not aware of reports of vessel strike for Southern DPS green sturgeon in the action area. Vessel strike was identified as a low-risk threat for Southern DPS green sturgeon (NMFS 2018).

9.5 Aquaculture

Aquaculture has the potential to impact protected species via entanglement and/or other interaction with aquaculture gear (i.e., buoys, nets, and lines), introduction or transfer of pathogens, impacts to habitat and benthic organisms, and water quality (Lloyd 2003; Clement 2013; Price and Morris 2013; Price et al. 2017).

In 2010, aquaculture operations in British Columbia amounted to a total harvested value of almost $534 million dollars, the majority ($511.5 million) being from salmon and other finfish. Salmon farming is British Columbia's largest agricultural export.[9] Currently in British Columbia, there are about 50 salmon aquaculture operations, mostly found near northern Vancouver Island.[10] Atlantic salmon aquaculture nets pens currently operate in Washington. There is no commercial salmon production in Oregon.

Salmon aquaculture in sea pens brings with it several concerns, chief among them being impacts from the accidental release of a nonnative species. An introduced species could outcompete native species for resources, or carry pathogens or parasites, causing native species' populations to decline or suffer. Since Southern Resident killer whales rely on salmon as prey, adverse impacts to native salmon populations from aquaculture could have detrimental effects to Southern Resident killer whales. Owing to recent incidents of escape, and to the large industry for salmon aquaculture in British Columbia in particular, much of this discussion will focus on Atlantic salmon.

There have been documented cases of accidentally released Atlantic salmon successfully reproducing in British Columbia, raising concerns about the possible establishment of the species, which could cause harm to native Pacific salmon (Volpe et al. 2000). There is evidence to suggest that salmon aquaculture is detrimental to wild native salmon populations, causing reductions in survival or abundance in wild populations (Ford and Myers 2008).

The parasite salmon lice (*Lepeophtheirus salmonis*) occurs naturally in salmon. Sea pens can create advantageous conditions for salmon lice to grow and be transmitted more expansively than they could under natural conditions. In severe cases of infection, salmon lice can cause erosion of the epidermis and exposure of the dermis, although mortality in wild salmon from salmon lice infection is rare. Sub-lethal effects include stress, changes in blood glucose or electrolytes, reduced hemocrits, and reduced swimming ability (Torrissen et al. 2013). Different species of Pacific salmon respond differently to salmon lice; Coho and pink salmon appear to more rapidly reject salmon lice than Chinook and chum (Johnson and Albright 1992; Jones et al. 2007).

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[9] https://www.dfo-mpo.gc.ca/aquaculture/pacific-pacifique/index-eng.html (Accessed 3/8/2021).
[10] https://www.cbc.ca/news/canada/british-columbia/fish-farming-bc-leases-1.4704626 (Accessed 3/8/2021).

The abundance of salmon lice has increased in years with abnormally warm water temperatures, possibly indicating that more frequent and stronger outbreaks can be expected as climate change persists (Torrissen et al. 2013). Aquaculture facilities regularly apply parasite treatments to manage salmon lice, giving rise to concerns about selection pressure and treatment resistance (Torrissen et al. 2013). There are some concerns about the indirect effects of common chemical treatments for salmon lice to other species like echinoderms, kelp, and spot prawns (*Pandalus platyceros*) (Strachan 2018).

There has been one major recent incident of sea pens failing and releasing nonnative Atlantic salmon into the action area. In August 2017, hundreds of thousands of Atlantic salmon escaped a fish farm operated by Cooke Aquaculture in Puget Sound near Anacortes, when a net pen failed. Subsequent investigation revealed that insufficient cleaning of the nets resulted in excessive biofouling on the net pen array. This caused increased drag on the mooring system, which led the weakening of attachment points between the moorings and the net pen to fail (Clark 2018). Initially, there were 305,000 Atlantic salmon in the net pen. After the collapse, Cooke Aquaculture was able to harvest or extract fish from the failed net pen. Still, there were between 242,959 and 262,659 Atlantic salmon released into Puget Sound. Subsequent efforts to extract escaped Atlantic salmon by beach seine, harvesting by tribes, the public, and Cooke Aquaculture recovered 56,810 Atlantic salmon, with between 186,149 to 205,849 fish not recovered. Veterinary assessment of recovered individuals shortly following the release showed no signs of bacterial, viral, or parasitic pathogens; subsequent examinations of post-released fish showed that the Atlantic salmon were contracting bacterial and viral pathogens endemic to Puget Sound (Clark 2018).

Later analysis did show that nearly 100 percent of the escaped Atlantic salmon sampled from the Cooke Aquaculture incident tested positive for piscine orthoreovirus, a virus in salmon aquaculture that causes pathological conditions like heart and skeletal inflammation. Atlantic salmon captured by anglers a few months later also tested positive for the virus (Kibenge et al. 2019). The strain of piscine orthoreovirus found in that study was very similar to another strain of the virus originating in Icelandic salmon farms. This lends support to the theory that the virus spread from fish egg transport because the eggs from the Iceland Atlantic fish farms was used to stock fish farms in Washington (Kibenge et al. 2019).

The chief concern is that the virus could cause fitness consequences for the native Pacific salmon populations, which are already facing difficulties. The British Columbia Ministry of Agriculture reported that about 80 percent of farmed Atlantic salmon were infected with piscine orthoreovirus. A study of farmed Atlantic salmon in British Columbia found that piscine orthoreovirus was detected in 95 percent of Atlantic salmon, and 35 to 47 percent of wild Pacific salmon, with the proportion of wild fish infected with the virus related to exposure to the fish farms (Morton et al. 2017).

Eight months after the net pen failure incident, Washington Governor Jay Inslee signed legislation placing restrictions on nonnative fish farms and banning Atlantic salmon farming in the state by 2025. Cooke Aquaculture, who operates the only remaining Atlantic salmon fish farms in the state, could be gone by 2022 when their lease expires.[11]

On December 20, 2019, damage caused to a sea pen by an electrical fire at a fish farm at Robertson Island north of Vancouver Island caused an estimated 20,000 Atlantic salmon to escape into Queen Charlotte Strait.[12] Canadian Prime Minister Justin Trudeau has pledged to move British Columbia's sea-based fish farms onto land by 2025.[13]

Current data suggest that interactions and entanglements of ESA-listed marine mammals and sea turtles with aquaculture gear are rare (Price et al. 2017). This may be because worldwide the number and density of aquaculture farms are low, and thus there is a low probability of interactions, or because they pose little risk of ESA-listed marine mammals and sea turtles. Nonetheless, given that in some aquaculture gear, such as that used in longline mussel farming, is similar to gear used in commercial fisheries, aquaculture may result in impacts similar to fisheries, including bycatch. There are very few reports of marine mammal interactions with aquaculture gear in the U.S. Pacific Ocean, although it is not always possible to determine if the gear animals become entangled in is from aquaculture or commercial fisheries (Price et al. 2017).

9.5.1 Hatcheries

There are several hundred public facilities (Federal, tribal, and state-operated) producing Pacific salmonids for release into fresh and sea water salmon habitat (Hatchery Scientific Review Group 2015). Salmon hatcheries contribute to the abundance of salmon populations and to the prey base of marine mammals that feed on salmon. However, there are several concerns with how artificial propagation of salmonids may impact natural salmon populations or the habitats essential to their survival. Concerns include a decrease in water quality due to fish waste or chemical disposal, increase in predation of natural fish stocks by hatchery-raised fish, and accidental introduction of non-native species that lead to predation or increased competition with natural salmon populations. Adverse effects to native salmon populations from hatchery fish could have subsequent effects to ESA-listed species that prey upon salmon (e.g., Southern Resident killer whale).

After completing the ocean stage, hatchery-origin fish generally return to tributaries concurrently with natural-origin salmon. Unless they are harvested or collected for broodstock or removal, hatchery-origin fish spawn in natural habitat. While hatcheries can provide a temporary demographic buffer for catastrophic declines in abundance, hatchery populations could eventually be more susceptible to large-scale climate forcing than natural populations due to the absence of behavioral, physiological, and genetic adaptation in the wild (Crozier et al. 2019).

[11] https://www.npr.org/sections/thesalt/2018/03/26/597019406/after-three-decades-washington-state-bans-atlantic-salmon-farms (Accessed 3/8/2021).
[12] https://mowi.com/caw/blog/2019/12/21/news-release-incident-at-robertson-island-causes-potential-fish-escape/ (Accessed 3/8/2021).
[13] https://www.alaskapublic.org/2019/12/27/fire-at-b-c-fish-farm-releases-thousands-of-atlantic-salmon/ (Accessed 3/8/2021).

9.6 Fisheries

Fisheries constitute an important and widespread use of the ocean resources throughout the action area. Fisheries can adversely affect fish populations, other species, and habitats. Direct effects of fisheries interactions on marine mammals and sea turtles include entanglement and entrapment, which can lead to fitness consequences or mortality because of injury or drowning. Non-target species are captured in fisheries (i.e., bycatch), and can represent a significant threat to non-target populations. Indirect effects include reduced prey availability, including overfishing of targeted species, and destruction of habitat.

9.6.1 Marine Mammals

Entrapment and entanglement in fishing gear is a frequently documented source of human-caused mortality in cetaceans (see Dietrich et al. 2007). Materials entangled tightly around a body part may cut into tissues, enable infection, and severely compromise an individual's health (Derraik 2002). Entanglements also make animals more vulnerable to additional threats (e.g., predation and vessel strikes) by restricting agility and swimming speed. The majority of marine mammals that die from entanglement in fishing gear likely sink at sea rather than strand ashore, making it difficult to accurately determine the extent of such mortalities. In excess of 97 percent of entanglement in cetaceans is caused by derelict fishing gear (Baulch and Perry 2014b). Figure 43 shows the number of confirmed whale entanglements per year detected off the U.S. west coast from 2001 to 2016 (Santora et al. 2020). The number of confirmed whale entanglements, most notably humpback whales, increased markedly throughout the 2014 to 2016 Pacific marine heat wave event.

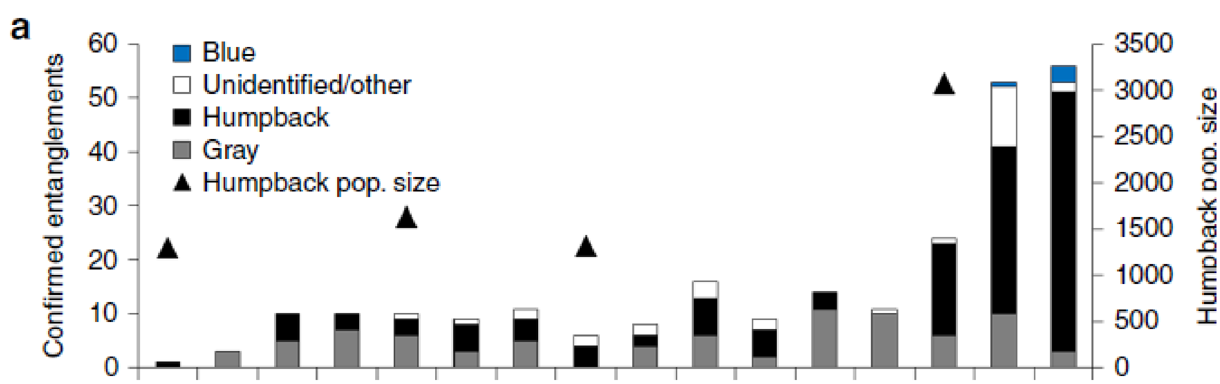

Figure 42. Trend in total confirmed whale entanglements per year detected off the U.S. west coast from 2001 to 2016, and estimated humpback whale population size (Santora et al. 2020).

The latest five-year average mortalities and serious injuries related to fisheries interactions for the ESA-listed marine mammal likely to be found in the action area within U.S. waters are given in Table 43 below (Carretta 2019b). Data represent only known mortalities and serious injuries; more, undocumented moralities and serious injuries for these and other marine mammals found within the action area have likely occurred.

Table 42. Five-year average mortalities and serious injuries related to fisheries interactions for Endangered Species Act-listed marine mammals within the action area.

Species	Mortality
Blue Whale	0.9
Fin Whale	≥0.5
Humpback Whale – Multiple ESA-listed DPSs	15.7
Sei Whale	0
Sperm Whale	N/A
Guadalupe Fur Seal	≥3.2

DPS=Distinct Population Segment

There have been reports of Guadalupe fur seals stranding with evidence of entanglement in fishing gear or other marine debris (Hanni et al. 1997). Previous bycatch data do not report any Guadalupe fur seal bycatch in fisheries in the U.S., including observed fisheries such as the driftnet and gillnet fisheries in California, and the groundfish trawl fishery in California, Washington and Oregon (NMFS 2000; NMFS 2013e). From the period of 2009 to 2013, there were 20 Guadalupe fur seals reported as injured or killed as a result of human-related injury; 13 dead, three seriously injured, and four non-seriously injured (Carretta et al. 2015). Several of these individuals were entangled in pieces of gillnet, trawl nets, or gear from an unidentified net fishery.

In addition to direct impacts like entanglement, marine mammals may also be subject to indirect impacts from fisheries. In a study of retrospective data, Jackson et al. (2001) concluded that ecological extinction caused by overfishing precedes all other pervasive human disturbance of coastal ecosystems, including pollution and anthropogenic climatic change.

Fisheries can have a profound influence on fish populations. Marine mammals probably consume at least as much fish as is harvested by humans (Kenney et al. 1985). Many cetacean species (particularly fin and humpback whales) are known to feed on species of fish that are harvested by humans (Carretta et al. 2016). Thus, competition with humans for prey is a potential concern. Reductions in fish populations, whether natural or human-caused, may affect the survival and recovery of ESA-listed marine mammal populations. Even species that do not directly compete with human fisheries could be indirectly affected by fishing activities through changes in ecosystem dynamics. However, in general the effects of fisheries on marine mammals through changes in prey abundance remain unknown in the action area.

9.6.2 Sea Turtles

Fishery interaction remains a major factor in sea turtle recovery and, frequently, the lack thereof. Wallace et al. (2010) estimated that worldwide, 447,000 sea turtles are killed each year from bycatch in commercial fisheries. Although sea turtle excluder devices and other bycatch reduction devices have significantly reduced the level of bycatch to sea turtles and other marine species in U.S. waters, mortality still occurs.

Leatherback turtles in the Pacific Ocean migrate about 11,265.4 kilometers (6,082.9 nautical miles) from nesting beaches in the tropical Pacific Ocean (e.g., Indonesia, Papua New Guinea, Costa Rica, Mexico) to foraging grounds off the U.S. West Coast. This migration puts leatherback turtles in proximity of numerous fisheries, especially longlines, increasing bycatch risk. Roe (2014) found areas of high bycatch risk in the North and Central Pacific Ocean. By far, however, the greatest areas of bycatch risk were in the jurisdictional waters of several Indo-Pacific nations, largely affecting nesting individuals. The authors pointed to the difficultly in coordinating management efforts between several countries as a barrier to reducing risk of bycatch and supporting leatherback turtle recovery.

9.6.3 Fish

ESA-listed salmon are incidentally caught in several fisheries that operate in the action area targeting non-listed salmon or other species. These include:

- Groundfish fisheries off the coasts of Washington, Oregon and California that operate under the Pacific Coast Groundfish Fishery Management Plan;
- Coastal pelagic species (i.e., northern anchovy, squid, Pacific sardine, Pacific mackerel, and jack mackerel) managed by the Pacific Fisheries Management Council under the Coastal Pelagic Species Fisheries Management Plan;
- Commercial salmon fisheries that operate under the Pacific Salmon Treaty;
- Salmon fisheries that are managed by the U.S. Pacific Fisheries Management Council under the Pacific Coast Management Plan;
- Salmon fisheries managed by the U.S. Fraser River Panel;
- Recreational fisheries that operate in the ocean and inland portions of the action area
- Tribal ceremonial and subsistence (gillnet, dip net and hook and line) fisheries in Puget Sound

Fisheries management plans developed for federally regulated fisheries with ESA-listed species bycatch are required to undergo section 7 consultation, including a NMFS' issued opinion and an ITS for those activities in the plan that are likely to adversely affect listed species. The ITS includes the anticipated amount of take (lethal and nonlethal) and reasonable and prudent measures with specific terms and conditions for mitigating and minimizing the adverse effects of the proposed action on ESA-listed species and designated critical habitat. Section 7 consultations also evaluate the secondary effects of fisheries removals on ESA-listed species that prey on fish (e.g., Southern Resident killer whales).

Pacific salmon fisheries provide for commercial, recreational, and tribal harvest in ocean and inland waters. Commercial ocean fisheries targeting Pacific salmon primarily use troll or hook-and-line gear, but gill nets are also used in commercial and tribal freshwater fisheries in inland waters. The broad geographic range and migration routes of salmon, from the inland tributaries to offshore areas, require comprehensive management by several stakeholder groups representing federal, state, tribal, and Canadian interests (NMFS 2019a).

While management of fishing activities have largely been focused on sustainability and protecting ESA-listed salmonids, management of salmon fisheries with respect to endangered Southern Resident killer whales is also part of the consultation process to evaluate impacts to fish stocks (listed or non-listed) that affect prey available for the Southern Residents (NMFS 2019a). A growing body of evidence documents how Southern Resident killer whales are affected by limitations of their primary prey, Chinook salmon (Matkin et al. 2017). Availability of Chinook for Southern Residents is likely affected by multiple factors including sound, competition from other salmon predators (e.g., other resident killer whales and pinnipeds), and fisheries harvest (Chasco et al. 2017). Both directed and incidental fishing activities may reduce the biomass available to Southern Resident killer whales by removing prey or by selecting for the larger salmon that are preferred by Southern Resident killer whales (NMFS 2008d). Reductions in Chinook salmon prey available due to fishery removals vary from year to year and by season and location. In years prior to ESA listings for salmon, fishery reductions were as high as 20-30 percent in some seasons and locations (NMFS 2019a). More recently, with ESA considerations for salmon and whales, seasonal reductions in inland and coastal waters have ranged from zero to 15 percent reductions. NMFS is currently working on a comprehensive analysis that assesses the effects of fisheries on Chinook salmon availability throughout the Southern Resident killer whales' geographic range, using a retrospective Fishery Regulation Assessment Model (FRAM)-based analysis similar to those used in previous fisheries consultations (NMFS 2008b; NMFS 2008c; NMFS 2011d; NMFS 2018a).

The whiting fishery (including at-sea, shore-based, and Tribal fisheries), which is a sector of the Pacific Coast groundfish fisheries, is estimated to have caught an average of 7,718 chinook each year from 2011 through 2015 (NMFS 2017b). Incidental capture of Chinook salmon in the bottom trawl sector of the groundfish fishery has sharply declined in recent years from an annual average over 15,000 from 2002-2003 to around 557 per year from 2011-2015 (NMFS 2017b). ESA section 7 consultations aim to limit the impact of ocean salmon fisheries on ESA-listed populations. For example, the maximum age-3 impact rate for 2015 ocean salmon fisheries on Sacramento River winter Chinook is 19 percent (PFMC 2015).

Coastal pelagic fisheries also have the potential to impact Pacific salmon through incidental capture or by removing prey biomass from the ecological system (Pacific Fishery Management Council 2014). Pelagic fisheries primarily operate off southern and central California, but there is a large sardine fishery off Oregon and Washington. Pacific sardine is an important source of forage for a large number of birds, marine mammals, and fish. The directed Pacific sardine fishery has been closed since July 1, 2015 because of low biomass, but small-scale directed fishing can still take place (NMFS 2019a).

Take of Southern DPS green sturgeon in federal fisheries was prohibited as a result of the ESA 4(d) protective regulations issued in June of 2010 (75 FR 30714). Green sturgeon are occasionally encountered as bycatch in Pacific Coast groundfish fisheries (Al-Humaidhi 2011). The estimated number of Southern DPS green sturgeon encountered in the federally-managed sectors of the groundfish fishery for 2013 to 2017 ranged from 1 to 16 per year (Richerson et al. 2019). Among state managed fisheries, bycatch was highest in the California halibut bottom trawl fishery, which encountered an estimated 118 to 641 Southern DPS green sturgeon annually from 2013 to 2017 (Richerson et al. 2019).The California nearshore groundfish sector caught an estimated 16 Southern DPS individuals in 2017, although from 2002-2016 none were caught in this fishery.

Approximately 50 to 250 green sturgeon are encountered annually by recreational anglers in the lower Columbia River (NMFS 2015f), of which 86 percent are expected to be Southern DPS green sturgeon based on the higher range estimate of Israel et al. (2009). Green sturgeon are also caught incidentally by recreational anglers fishing in Washington outside of the Columbia River (NMFS 2015f). Southern DPS green sturgeon are also captured and released by California recreational anglers. Based on self-reported catch card data, an average of 193 green sturgeon were caught and released annually by California anglers from 2007 to 2013 (NMFS 2015f). Recreational catch and release can potentially result in indirect effects on green sturgeon, including reduced fitness and increased vulnerability to predation. However, the magnitude and impact of these effects on Southern DPS green sturgeon are not well studied.

The main source of eulachon bycatch are the west coast shrimp fisheries (NMFS 2017e). Offshore trawl fisheries for ocean shrimp (*Pandalus jordani*) occur off the west coast of North America from the west coast of Vancouver Island to Cape Mendocino, California (Hannah and Jones 2007) and in British Columbia, Canada. *Pandalus jordani* is known as the smooth pink shrimp in British Columbia, ocean pink shrimp or smooth pink shrimp in Washington, pink shrimp in Oregon, and Pacific Ocean shrimp in California. The ocean shrimp season is open April 1 through October 31 in California, Oregon and Washington and ships deliver catch to shore-based processors. Total coast-wide ocean shrimp landings have ranged from a low of 1,888 metric tons in 1957 to a high of 46,494 metric tons in 2015 (NMFS 2017e).

Prior to 2000, eulachon bycatch in the ocean shrimp fishery ranged from 32 to 61 percent of the total catch (Hannah and Jones 2007). Eulachon occur as bycatch in shrimp trawl fisheries off the coasts of Washington, Oregon, California, and British Columbia (Gustafson et al. 2010). Ward et al. (2015) found that the coastal areas just south of Coos Bay, Oregon; between the Columbia River and Grays Harbor, Washington; and just south of La Push, Washington were consistent hotspots of eulachon bycatch across years. The previously depressed and currently increasing abundance of the Southern DPS of eulachon (James et al. 2014) are likely contributing to the increased levels of eulachon bycatch reported for 2012 to 2014. The dramatic increases in the level of eulachon bycatch in both the Washington and Oregon ocean shrimp trawl fisheries in 2012 and 2013 occurred in spite of regulations requiring the use of bycatch reduction devices. It is unclear why bycatch ratios were highest in the Washington, intermediate in the Oregon, and lowest in the California sectors of the ocean shrimp trawl fishery in 2012 and 2013. However, the bycatch ratio increased in Oregon and decreased in Washington in 2014 compared to the previous two-year period. Use of bycatch reduction devices in offshore shrimp trawl fisheries, which was mandated beginning in 2003 in Washington and Oregon has substantially reduced bycatch of fin fish in these fisheries (Hannah and Jones 2007; Frinodig et al. 2009).

9.7 Pollution

Within the action area, pollution poses a threat to ESA-listed marine mammals and sea turtles. Pollution can come in the form of marine debris, pesticides, contaminants, and hydrocarbons.

9.7.1 Marine Debris

Data on marine debris in some locations of the action area is largely lacking; therefore, it is difficult to draw conclusions as to the extent of the problem and its impacts on populations of ESA-listed species in the Northeast Pacific Ocean, but we assume similar effects from marine debris documented within other ocean basins could also occur to species from marine debris.

Cetaceans are impacted by marine debris, which includes plastics, glass, metal, polystyrene foam, rubber, and derelict fishing gear (Baulch and Perry 2014a; Li et al. 2016). Over half of cetacean species (including blue, fin, humpback, sei, and sperm whales) are known to ingest marine debris (mostly plastic), with up to 31 percent of individuals in some populations containing marine debris in their guts and being the cause of death for up to 22 percent of individuals found stranded on shorelines (Baulch and Perry 2014b). A recent study showed that microplastics were present in nearly all fecal samples from Southern Resident killer whales (Harlacher 2020).

Plastic waste in the ocean can leach chemical additives into the water or these additives, such as brominated flame retardants, stabilizers, phthalate esters, biphenyl A, and nonylphenols (Panti et al. 2019). Additionally, plastic waste chemically attracts hydrocarbon pollutants such as polychlorinated biphenyl and dichlorodiphenyltrichloroethane. Individuals can mistakenly consume these wastes containing elevated levels of toxins instead of their prey. Once consumed, plastics can act as nutritional diluents in the gut, making the animal feel satiated before it has acquired the necessary amount of nutrients required for general fitness (reviewed in (Machovsky-Capuska et al. 2019)). Plastics may therefore influence the nutritional niches of animals in higher trophic levels, such as Guadalupe fur seals and other pinnipeds (Machovsky-Capuska et al. 2019).

Given the limited knowledge about the impacts of marine debris on marine mammals, it is difficult to determine the extent of the threats that marine debris poses to marine mammals. However, marine debris is consistently present and has been found in marine mammals in and near the action area. In 2008, two sperm whales stranded along the California coast, with an assortment of fishing related debris (e.g., net scraps, rope) and other plastics inside their stomachs (Jacobsen et al. 2010). One whale was emaciated, and the other had a ruptured stomach. It was suspected that gastric impactions was the cause of both deaths. Jacobsen et al.

(2010) speculated the debris likely accumulated over many years, possibly in the North Pacific gyre that will carry derelict Asian fishing gear into eastern Pacific Ocean waters.

Ingestion of marine debris can be a serious threat to sea turtles. When feeding, sea turtles (e.g., leatherback turtles) can mistake debris (e.g., tar and plastic) for natural food items, especially jellyfish, which are a primary prey. Some types of marine debris may be directly or indirectly toxic, such as oil. One study found plastic in 37 percent of dead leatherback turtles and determined that nine percent of those deaths were a direct result of plastic ingestion (Mrosovsky et al. 2009). Plastic ingestion is very common in leatherback turtles and can block gastrointestinal tracts leading to death (Mrosovsky et al. 2009). Other types of marine debris, such as discarded or derelict fishing gear and cargo nets, may entangle and drown sea turtles of all life stages.

Plastic debris is a major concern because it degrades slowly and many plastics float. The floating debris is transported by currents throughout the oceans and has been discovered accumulating in oceanic gyres (Law et al. 2010). Additionally, plastic waste in the ocean chemically attracts hydrocarbon pollutants. Marine mammals, sea turtles, and fish can mistakenly consume these wastes containing elevated levels of toxins instead of their prey. It is expected that marine mammals, sea turtles, and fish may be exposed to marine debris over the course of the action although the risk of ingestion or entanglement and the resulting impacts are uncertain at the time of this consultation.

9.7.2 Pollutants and Contaminants

Exposure to pollution and contaminants have the potential to cause adverse health effects in marine species. Marine ecosystems receive pollutants from a variety of local, regional, and international sources, and their levels and sources are therefore difficult to identify and monitor (Grant and Ross 2002). Marine pollutants come from multiple municipal, industrial, and household as well as from atmospheric transport (Iwata 1993; Grant and Ross 2002; Garrett 2004; Hartwell 2004). Contaminants may be introduced by rivers, coastal runoff, wind, ocean dumping, dumping of raw sewage by boats and various industrial activities, including offshore oil and gas or mineral exploitation (Grant and Ross 2002; Garrett 2004; Hartwell 2004).

The accumulation of persistent organic pollutants, including polychlorinated-biphenyls, dibenzo-p-dioxins, dibenzofurans and related compounds, through trophic transfer may cause mortality and sub-lethal effects in long-lived higher trophic level animals (Waring et al. 2016), including immune system abnormalities, endocrine disruption, and reproductive effects (Krahn et al. 2007a). Persistent organic pollutants may also facilitate disease emergence and lead to the creation of susceptible "reservoirs" for new pathogens in contaminated marine mammal populations (Ross 2002). Recent efforts have led to improvements in regional water quality and monitored pesticide levels have declined, although the more persistent chemicals are still detected and are expected to endure for years (Mearns 2001; Grant and Ross 2002).

In a small and imperiled population, these pollutant effects can be especially deleterious, as they could work in concert along with other stressors (e.g., reductions in prey), leading to reduced fitness for an individual. For example, in Southern Resident killer whales, contamination from pollutants could lead to endocrine disruption (delayed development, changes to metabolism, reduced perinatal survival), and compromised immune systems (Mongillo et al. 2016).

Numerous factors can affect concentrations of persistent pollutants in marine mammals, such as age, sex and birth order, diet, and habitat use (Mongillo et al. 2012). In marine mammals, pollutant contaminant load for males increases with age, whereas females pass on contaminants to offspring during pregnancy and lactation (Addison and Brodie 1987; Borrell et al. 1995). Pollutants can be transferred from mothers to juveniles at a time when their bodies are undergoing rapid development, putting juveniles at risk of immune and endocrine system dysfunction later in life (Krahn et al. 2009).

Pollutants and contaminants cause adverse health effects in pinnipeds. Acute toxicity events may result in mass mortalities; repeated exposure to lower levels of contaminants may also result in immune suppression and/or endocrine disruption (Atkinson et al. 2008). In addition to hydrocarbons and other persistent chemicals, pinnipeds may become exposed to infectious diseases (e.g., Chlamydia and leptospirosis) through polluted waterways(Aguirre et al. 2007).

In sea turtles, a variety of heavy metals (e.g., arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver and zinc) have been found in tissues in levels that increase with sea turtle size (Godley et al. 1999; Saeki et al. 2000; Anan et al. 2001; Fujihara et al. 2003; Gardner et al. 2006; Storelli et al. 2008; Barbieri 2009; Garcia-Fernandez et al. 2009). Cadmium has been found in leatherback turtles at the highest concentration compared to any other marine vertebrate (Gordon et al. 1998; Caurant et al. 1999). Newly emerged hatchlings have higher concentrations than are present when laid, suggesting that metals may be accumulated during incubation from surrounding sands (Sahoo et al. 1996).

Sea turtle tissues have been found to contain organochlorines and many other persistent organic pollutants. Polychlorinated biphenyl (better known as PCB, found in engine coolants) concentrations in sea turtles are reportedly equivalent to those in some marine mammals, with liver and adipose levels of at least one congener being exceptionally high (PCB 209: 500-530 ng/g wet weight; Davenport 1990; Oros 2009). PCBs have been found in leatherback turtles at concentrations lower than expected to cause acute toxic effects, but might cause sub-lethal effects on hatchlings (Stewart 2011). Further study has shown that PBDEs in leatherback eggs show a negative correlation to hatching success (De Andrés et al. 2016).

Green sturgeon are vulnerable to pollutants and pesticides, with such contaminants posing a risk to eggs, larvae, and juveniles, potentially causing reduced growth, injury, or mortality (NMFS 2018b). Accumulation of PCBs has been shown in Chinook and Coho salmon in Puget Sound, and PCBs have been found in all species of Pacific salmon in Alaska and the Columbia River. The effects of accumulation of PCBs to salmon are unknown, though it is thought possible that if the PCBs are passed to the eggs, it could affect reproductive success, or inhibit immune response in juveniles (O'Neill et al. 1998).

Because POPs are both ubiquitous and persistent in the environment, marine mammals, sea turtles, and other forms of marine life will continue to be exposed to POPs for all of their lives. The effects of POPs to ESA-listed species are unknown and not directly studied, but it is possible that the effects could be sub-lethal and long-term in nature, and include impacting reproduction, immune function, and endocrine activity. These are effects that would become more apparent as time goes on. At present, however, the effects of POPs in ESA-listed species are not currently well known.

9.7.3 Oil Spills

There has never been a large-scale oil spill in the action area, but numerous small-scale vessel spills likely occur. A nationwide study examining vessel oil spills from 2002 through 2006 found that over 1.8 million gallons of oil were spilled from vessels in all U.S. waters (Dalton and Jin 2010). In this study, "vessel" included numerous types of vessels, including barges, tankers, tugboats, and recreational and commercial vessels, demonstrating that the threat of an oil spill can come from a variety of boat types. In addition to vessels, oil spills can come from other sources like pipelines and rail cars, but in this discussion, we focus on spills to water.

The substantial volume of shipping traffic and the presence of refineries in the action area create the risk of a catastrophic oil spill that could affect listed species and their prey. Due to its proximity to Alaska's crude oil supply, Puget Sound is one of the leading petroleum refining centers in the United States. In the state of Washington alone, 20 billion gallons of oil move through the state annually, with most of it transported via vessel (i.e., 50 percent or more over the years 2007 to 2018) (Ecology 2019). The Trans Mountain pipeline expansion in British Columbia would increase the amount of oil transported, from 300,000 barrels currently to 890,000 once it comes online in 2022. Once completed, the pipeline is expected to result in an increase in oil tanker traffic in the region; currently, the Port of Vancouver has between 30 and 50 crude oil tankers annually. This is predicted to increase to up to 400 crude oil tankers per year once the Trans Mountain pipeline expansion is complete (NEB 2019).

In keeping with the national scale study discussed earlier, most spill incidents in the action area are small scale in nature, but the increasing oil production, processing, and transport in the action area mean there is the possibility of a large-scale event. For example, in Washington from 2015 to 2019, there were 2,225 reported oil spills to water incidents, with the majority (95.3 percent) of the incidents spilling less than 100 gallons, and 32 percent of total spills coming from incidents where only one gallon was released[14]. In Oregon in 2018, around 500 oil spills occurred, with most classified as "small spill" (less than 42 gallons) (PSBC 2019). Between 2017 and 2019, Vancouver Island reported a total of 1,446 spill incidents, with most (1,429) classified

[14] From the Washington State Department of Ecology - Spills Program Integrated Information System (SPIIS) Database

as "Code 1" spills, described as generally smaller spills that are easy to clean up, in contrast to Code 2 spills, which are classified as substantial spills not easily confined (EPP 2019). Although the individual spills reported are small or minor, it is important to point out the fact that oil spills occur frequently, there are thousands of them overall, and that there could be cumulative effects to exposed species as a result.

Although these spills occurred many years ago outside the action area for this consultation, given the long life spans and broad distribution of several of the species considered in this consultation, it is possible that those populations could be impacted by long-term, sub-lethal effects from those spills. The long-term effects of repeated ingestion of sub-lethal quantities of petroleum hydrocarbons on marine mammals are not well understood, either. As a result, the magnitude of the risks posed by oil discharges in the proposed action area is difficult to precisely quantify or estimate.

9.8 Aquatic Nuisance Species

Aquatic nuisance species are aquatic and terrestrial organisms, introduced into new habitats throughout the U.S. and other areas of the world that produce harmful impacts on aquatic ecosystems and native species (http://www.anstaskforce.gov). They are also referred to as invasive, alien, or non-indigenous species. Invasive species have been referred to as one of the top four threats to the world's oceans (Raaymakers and Hilliard 2002; Raaymakers 2003; Terdalkar et al. 2005; Pughiuc 2010). Introduction of these species is cited as a major threat to biodiversity, second only to habitat loss (Wilcove et al. 1998). A variety of vectors are thought to have introduced non-native species including, but not limited to aquarium and pet trades, recreation, and ballast water discharges from ocean-going vessels. Common impacts of invasive species are alteration of habitat and nutrient availability, as well as altering species composition and diversity within an ecosystem (Strayer 2010). Shifts in the base of food webs, a common result of the introduction of invasive species, can fundamentally alter predator-prey dynamics up and across food chains (Moncheva and Kamburska 2002), potentially affecting prey availability and habitat suitability for ESA-listed species. They have been implicated in the endangerment of 48 percent of ESA-listed species (Czech and Krausman 1997). Currently, there is little information on the level of aquatic nuisance species and the impacts of these invasive species may have on marine mammals, fish, and sea turtles in the action area through the duration of the project. Therefore, the level of risk and degree of impact to ESA-listed marine mammals, sea turtles, and fish is unknown.

In the action area, there are several aquatic nuisance and introduced species that have the potential to impact ESA-listed species. Non-native species like striped bass (*Morone saxatillis*) may prey upon young green sturgeon, while non-native Japanese eelgrass (*Zostera japonica*) binds sediments that can reduce unvegetated sand feeding habitat for green sturgeon (Moser et al. 2016).

9.9 Anthropogenic Sound

The ESA-listed species that occur in the action area are regularly exposed to several sources of natural and anthropogenic sounds. A wide variety of anthropogenic and natural sources contribute to ocean noise throughout the world's oceans. Anthropogenic sources of noise that are most likely to contribute to increases in ocean noise are vessel noise from commercial shipping and general vessel traffic, oceanographic research, oil, gas and mineral exploration, underwater construction, geophysical (seismic) surveys, Naval and other sources of sonar, and underwater explosions (Richardson et al. 1995f; Hatch and Wright 2007b).

Noise is of particular concern to marine mammals because many species use sound as a primary sense for navigating, finding prey, avoiding predators, and communicating with other individuals.

Noise in the marine environment has received a lot of attention in recent years and is likely to continue to receive attention in the foreseeable future. There is a large and variable natural component to the ambient noise level as a result of events such as earthquakes, rainfall, waves breaking, and lightning hitting the ocean as well as biological noises such as those from snapping shrimp, other crustaceans, fishes, and the vocalizations of marine mammals (Crawford and Huang 1999; Patek 2002; Hildebrand 2004b). However, several studies have shown that anthropogenic sources of noise have increased ambient noise levels in the ocean over the last 50 years (NRC 1994; Richardson et al. 1995f; NRC 2000; NRC 2003a; Jasny et al. 2005; NRC 2005b). Much of this increase is due to increased shipping as ships become more numerous and of larger tonnage (NRC 2003a). Commercial fishing vessels, cruise ships, transport boats, airplanes, helicopters and recreational boats all contribute sound into the ocean (NRC 2003a). The military uses sound to test the systems of Navy vessels as well as for naval operations. In some areas where oil and gas production takes place, noise originates from the drilling and production platforms, tankers, vessel and aircraft support, seismic surveys, and the explosive removal of platforms (NRC 2003a).

Andrew et al. (2002) compared ocean ambient sound from the 1960s to the 1990s from a receiver off the California coast. The data showed an increase in ambient noise of approximately 10 dB in the frequency ranges of 20 to 80 Hertz and 200 to 300 hertz, and about 3 dB at 100 hertz over a 33-year period. Each 3 dB increase is noticeable to the human ear as a doubling in sound level. A possible explanation for the rise in ambient noise is the increase in shipping noise. There are approximately 11,000 supertankers worldwide, each operating approximately 300 days per year, each producing constant broadband noise at typical source levels of 198 dB (Hildebrand 2004b). Generally the most energetic regularly operated sound sources are seismic airgun arrays from approximately 90 vessels with typically 12 to 48 individual guns per array, firing about every 10 seconds (Hildebrand 2004b).

9.9.1 Seismic Surveys

Similar to the proposed action, offshore seismic surveys involve the use of high-energy sound sources operated in the water column to probe below the seafloor. Numerous seismic surveys have been conducted off the west coast over the past several decades. Unlike other regions (e.g., Gulf of Mexico) where the large majority of seismic activity is associated with oil and gas development, seismic surveys conducted in the action area are primarily for scientific research, to identify possible seafloor or shallow-depth geologic hazards, and to locate potential archaeological resources and benthic habitats that should be avoided.

For past scientific research seismic surveys in the action area, NMFS issued permits for seismic activity conducted near marine mammals and ESA-listed sea turtles. MMPA and ESA permits specify the conditions under which researchers can operate seismic sound sources, such as airguns, including mitigation measure to minimize adverse effects to protected species. In the action area, other past seismic surveys include one in 2012 (over the Cascadia Thrust Zone), which resulted in a no jeopardy or adverse modification determination.

9.9.2 Active Sonar

Active sonar emits high-intensity acoustic energy and receives reflected and/or scattered energy. A wide range of sonar systems are in use for both civilian and military applications. The primary sonar characteristics that vary with application are the frequency band, signal type (pulsed or continuous), rate of repetition, and source level. Sonar systems can be divided into categories, depending on their primary frequency of operation; low frequency for one kilohertz and less, mid frequency for one to 10 kilohertz; high frequency for 10 to 100 kilohertz; and very high frequency for greater than 100 kilohertz (Hildebrand 2004a). Low frequency systems are designed for long-range detection (Popper et al. 2014a). The effective source level of an low-frequency active array, when viewed in the horizontal direction, can be 235 dB re 1μPa-m or higher (Hildebrand 2004a). Signal transmissions are emitted in patterned sequences that may last for days or weeks. An example of a low-frequency active sonar system is the U.S. Navy Surveillance Underwater Towed Array Sensor System (SURTASS), discussed in more detail below (See Section 8.10). Mid-frequency military sonars include tactical anti-submarine warfare sonars, designed to detect submarines over several tens of kilometers, depth sounders and communication sonars. High-frequency military sonars includes those incorporated into weapons (torpedoes and mines) or weapon countermeasures (mine countermeasures or anti-torpedo devices), as well as side-scan sonar for seafloor mapping. Commercial sonars are designed for fish finding, depth sounding, and sub-bottom profiling. They typically generate sound at frequencies of 3 to 200 kilohertz, with source levels ranging from 150 to 235 dB re 1μPa-m (Hildebrand 2004a). Depth sounders and sub-bottom profilers are operated primarily in nearshore and shallow environments, however, fish finders are operated in both deep and shallow areas.

9.9.3 Vessel Sound and Commercial Shipping

Individual vessels produce unique acoustic signatures, although these signatures may change with vessel speed, vessel load, and activities that may be taking place on the vessel. Sound levels are typically higher for the larger and faster vessels. Peak spectral levels for individual commercial vessels are in the frequency band of ten to 50 hertz and range from 195 dB re: μPa^2-s at 1 m for fast-moving (greater than 20 knots) supertankers to 140 dB re: μPa^2-s at 1 m for smaller vessels (NRC 2003a). Although large vessels emit predominantly low frequency sound, studies report broadband sound from large cargo vessels above two kilohertz, which may interfere with important biological functions of cetaceans (Holt 2008). At frequencies below 300 hertz, ambient sound levels are elevated by 15 to 20 dB when exposed to sounds from vessels at a distance (McKenna et al. 2013b).

Much of the increase in sound in the ocean environment over the past several decades is due to increased shipping, as vessels become more numerous and of larger tonnage (NRC 2003a; Hildebrand 2009; McKenna et al. 2012). Shipping constitutes a major source of low-frequency (five to 500 hertz) sound in the ocean (Hildebrand 2004a), particularly in the Northern Hemisphere where the majority of vessel traffic occurs. While commercial shipping contributes a large portion of oceanic anthropogenic noise, other sources of maritime traffic can also impact the marine environment. These include recreational boats, whale-watching boats, research vessels, and ships associated with oil and gas activities. See Section 9.4 for a detailed discussion of the amount of vessel traffic from ports within the action area.

Vessel noise can result from several sources including propeller cavitation, vibration of machinery, flow noise, structural radiation, and auxiliary sources such as pumps, fans and other mechanical power sources. Kipple and Gabriele (2007) measured sounds emitted from 38 vessels ranging in size from 14 to 962 feet at speeds of 10 knots and at a distance of 500 yards from the hydrophone. Sound levels ranged from a minimum of 157 to a maximum of 182 dB re 1 μPa-m, with sound levels showing an increasing trend with both increasing vessel size and with increasing vessel speed. Vessel sound levels also showed dependence on propulsion type and horsepower. McKenna et al. (2012) measured radiated noise from several types of commercial ships, combining acoustic measurements with ship passage information from Automatic Identification System (AIS). On average, container ships and bulk carriers had the highest estimated broadband source levels (186 dB re 1 lPa2 20 to 1000 hertz), despite major differences in size and speed. Differences in the dominant frequency of radiated noise were found to be related to ship type, with bulk carrier noise predominantly near 100 hertz while container ship and tanker noise was predominantly below 40 hertz. The tanker had less acoustic energy in frequencies above 300 hertz, unlike the container and bulk carrier.

Sound emitted from large vessels, such as shipping and cruise ships, is the principal source of low frequency noise in the ocean today, and marine mammals are known to react to or be affected by that noise (Richardson et al. 1995d; Foote et al. 2004; Hildebrand 2005; Hatch and Wright 2007a; Holt et al. 2008; Melcon et al. 2012; Anderwald et al. 2013; Kerosky et al. 2013; Erbe et al. 2014; Guerra et al. 2014; May-Collado and Quinones-Lebron 2014; Williams et al. 2014b). Several studies have demonstrated short-term effects of disturbance on humpback whale behavior (Hall 1982; Baker et al. 1983; Krieger and Wing 1984; Bauer and Herman 1986), but the long-term effects, if any, are unclear or not detectable. Carretta et al. (2001) and Jasny et al. (2005) identified the increasing levels of anthropogenic noise as a habitat concern for whales and other cetaceans because of its potential effect on their ability to communicate. Significant changes in odontocete behavior attributed to vessel noise have been documented up to at least 5.2 kilometers away from the vessel (Pirotta et al. 2012).

Erbé (2002c) recorded underwater noise of whale-watching boats in the popular killer whale-watching region of southern British Columbia and northwestern Washington State. Source levels ranged from 145 to 169 dB re 1 Pa-m and increased as the vessel's speed increased. Based on sound propagation models, Erbé (2002c) concluded that the noise of fast boats would be audible to killer whales over 16 kilometers, would mask killer whale calls over 14 kilometers, would elicit behavioral response over 200 meters, and would cause a temporary threshold shifts of 5 dB within 450 meters after 30 to 50 minutes of exposure. Erbé (2002c) concluded that boats cruising at slow speeds would be audible and would cause masking at 1 kilometers, would elicit behavioral responses at 50 meters, and would result in temporary threshold shifts at 20 meters.

Galli et al. (2003) measured ambient noise levels and source levels of whale-watch boats in Haro Strait. They measured ambient noise levels of 91 dB (at frequencies between 50 and 20,000 hertz) on extremely calm days (corresponding to sea states of zero) and 116 dB on the roughest day on which they took measures (corresponding to a sea state of ~5). Mean sound spectra from acoustic moorings set off Cape Flattery, Washington, showed that close ships dominated the sound field below 10 kilohertz while rain and drizzle were the dominant sound sources above 20 kilohertz. At these sites, shipping noise dominated the sound field about 10 to 30 percent of the time but the amount of shipping noise declined as weather conditions deteriorated. The large ships they measured produced source levels that averaged 184 dB-m ± 4 dB, which was similar to the 187 dB at 1 meter reported by Greene (1995). The engines associated with the boats in their study produced sounds in the 0.5 to 8.0 kilohertz range at source levels comparable to those of killer whale vocalizations. They concluded that those boats in their study that travelled at their highest speeds proximate to killer whales could make enough noise to make hearing difficult for the whales.

In addition to the disturbance associated with the presence of vessel, the vessel traffic affects the acoustic ecology of Southern Resident killer whales, which would affect their social ecology. Foote et al. (2004) compared recordings of Southern Resident killer whales that were made in the presence or absence of boat noise in Puget Sound during three time periods between 1977 and 2003. They concluded that the duration of primary calls in the presence of boats increased by about 15 percent during the last of the three time periods (2001 to 2003). At the same time, Holt et al. (2009) reported that Southern Resident killer whales in Haro Strait off the San Juan Islands in Puget Sound, Washington, increased the amplitude of their social calls in the face of increased sounds levels of background noise. Although the costs of these vocal adjustments remains unknown, Foote et al. (2004) suggested that the amount of boat noise may have reached a threshold above which the killer whales needs to increase the duration of their vocalization to avoid masking by the boat noise.

Commercial shipping traffic is a major source of low frequency (5 to 500 hertz) human generated sound in the world's oceans (Simmonds and Hutchinson 1996; NRC 2003a). The radiated noise spectrum of merchant ships ranges from 20 to 500 hertz and peaks at approximately 60 hertz. Ross (Ross 1976) estimated that between 1950 and 1975 shipping had caused a rise in ambient ocean noise levels of 10 dB; based on his estimates, Ross predicted a continuously increasing trend in ocean ambient noise of 0.55 dB per year. Chapman and Price

(2011) recorded low frequency deep ocean ambient noise in the Northeast Pacific Ocean from 1976 to 1986 and reported that the trend of 0.55 dB per year predicted by Ross (1976) persisted until at least around 1980; afterward, the increase per year was significantly less, about 0.2 dB per year. Within the action area identified in this opinion, the vessel sound inside the western half of the Strait of Juan de Fuca and off the Washington coast comes from cargo ships (86 percent), tankers (6 percent), and tugs (5 percent) (NMFS 2008d citing Mintz and Filadelfo 2004a, 2004b)). Williams et al. (2014a) measured ocean noise levels at 12 sites in the Canadian Pacific Ocean, including Haro Strait, and reported that noise levels were high enough to reduce the communication spaces for fin, humpback and killer whales under typical (median) conditions by 1, 52 and 62 percent, respectively, and 30, 94 and 97 percent under noisy conditions.

Bassett et al. (2012) paired one year of AIS data with hydrophone recordings in Puget Sound's Admiralty Inlet to assess ambient noise levels and the contribution of vessel noise to these levels. Results suggested ambient noise levels between 20 hertz and 30 kilohertz were largely driven by vessel activity and that the increases associated with vessel traffic were biologically significant. Throughout the year, at least one AIS-transmitting vessel was within the study area 90 percent of the time and multiple vessels were present 68 percent of the time. A vessel noise budget showed cargo vessels accounted for 79 percent of acoustic energy, while passenger ferries and tugs had lower source levels but spent substantially more time in the study site and contributed 18 percent of the energy in the budget. All vessels generated acoustic energy at frequencies relevant to all marine mammal functional hearing groups.

9.10 Military Activities

Many researchers have described behavioral responses of marine mammals to the sounds produced by helicopters and fixed-wing aircraft, boats and ships, as well as dredging, construction, geological explorations, etc. (Richardson et al. 1995f). Most observations have been limited to short-term behavioral responses, which included cessation of feeding, resting, or social interactions. Smultea et al. (2008b) documented a recognized "stress behavioral reaction" by a group of sperm whales in response to small aircraft fly-bys. The group ceased forward movement, moved closer together in a parallel flank-to-flank formation, and formed a fan-shaped semi-circle with the lone calf remaining near the middle of the group. In-air noise levels from aircraft can be problematic for marine life, and that sound can also extend into water. Kuehne et al. (2020) found that sounds from military aircraft at Whidbey Island, Washington, were detectable 30 meters below the water surface at levels of 134 dB re 1 μPa rms.

The U.S. Navy conducts training, testing, and other military readiness activities on range complexes throughout coastal and offshore areas in the United States and on the high seas. The U.S. Navy's Northwest Training and Testing range complex overlaps with the action area for the National Science Foundation's seismic survey. During training, existing and established weapon systems and tactics are used in realistic situations to simulate and prepare for combat. Activities include: routine gunnery, missile, surface fire support, amphibious assault and landing, bombing, sinking, torpedo, tracking, and mine exercises. Testing activities are conducted for different purposes and include at-sea research, development, evaluation, and experimentation. The U.S.

Navy performs testing activities to ensure that its military forces have the latest technologies and techniques available to them. The majority of the training and testing activities the U.S. Navy conducts in the action area are similar, if not identical to activities that have been occurring in the same locations for decades, therefore the ESA-listed species located within the action area have been exposed to these military activities often and repeatedly.

The U.S. Navy's activities produce sound and visual disturbance to marine mammals and sea turtles throughout the action area. Anticipated impacts from harassment due to the U.S. Navy's activities include changes from foraging, resting, milling, and other behavioral states that require low energy expenditures to traveling, avoidance, and behavioral states that require higher energy expenditures. Based on the currently available scientific information, behavioral responses that result from stressors associated with these training and testing activities are expected to be temporary and will not affect the reproduction, survival, or recovery of these species. Sound produced during U.S. Navy activities is also expected to result in instances of TTS and PTS to marine mammals and sea turtles. Sound produced during U.S. Navy activities is also expected to result in instances of TTS and PTS to marine mammals and sea turtles. The U.S. Navy's activities constitute a federal action and take of ESA-listed marine mammals and sea turtles considered for these activities have previously undergone separate ESA section 7 consultations. Through these consultations with NMFS, the U.S. Navy has implemented monitoring and conservation measures to reduce the potential effects of underwater sound from activities on ESA-listed resources in the Pacific Ocean. Conservation measures include employing visual observers and implementing mitigation zones during activities using active sonar and explosives.

The Air Force conducts training and testing activities on range complexes on land and in U.S. waters. Aircraft operations and air-to-surface activities may occur in the action area). Air Force activities generally involve the firing or dropping of munitions (e.g., bombs, missiles, rockets, and gunnery rounds) from aircraft towards targets located on the surface, though Air Force training exercises may also involve boats. These activities have the potential to impact ESA-listed species by physical disturbance, boat strikes, debris, ingestion, and effects from noise and pressure produced by detonations. Air Force training and testing activities constitute a federal action and take of ESA-listed species considered for these Air Force activities have previously undergone separate section 7 consultations.

9.11 Scientific Research Activities

Regulations for section 10(a)(1)(A) of the ESA allow issuance of permits authorizing take of certain ESA-listed species for the purposes of scientific research. Prior to the issuance of such a permit, the proposal must be reviewed for compliance with section 7 of the ESA. Scientific research permits issued by NMFS currently authorize studies of ESA-listed species in the Northeast Pacific Ocean, some of which extend into portions of the action area for the proposed action. Marine mammals and sea turtles have been the subject of field studies for decades. The primary objective of most of these field studies has generally been monitoring populations or gathering data for behavioral and ecological studies. Over time, NMFS has issued dozens of permits on an annual basis for various forms of "take" of marine mammals, sea turtles and fish in the action area from a variety of research activities. There have been numerous research permits issued since 2009 under the provisions of both the MMPA and ESA authorizing scientific research on marine mammals and sea turtles, including for research in the action area.

Authorized research on ESA-listed marine mammals includes aerial and vessel surveys, close approaches, photography, videography, behavioral observations, active acoustics, remote ultrasound, passive acoustic monitoring, biological sampling (i.e., biopsy, breath, fecal, sloughed skin), and tagging. Research activities involve non-lethal "takes" of these marine mammals.

Authorized research on sea turtles includes close approach, capture, handling and restraint, tagging, blood and tissue collection, lavage, ultrasound, imaging, antibiotic (tetracycline) injections, captive experiments, laparoscopy, and mortality. Most research activities involve authorized sub-lethal "takes," with some resulting mortality.

Authorized research on fish includes capture, handling and restraint, tagging, blood and tissue sampling, and mortality. Most research activities involve authorized sub-lethal "takes", with some resulting in mortality.

Research permits for ESA-listed fish are authorized under section 10(a)(1)(A) and issued at the West Coast Region, or the research is authorized under section 4(d) rules, for threatened fish. The consultations that took place on the issuance of these ESA scientific research permits each found that the authorized research activities will have no more than short-term effects and were not determined to result in jeopardy to the species or adverse modification of designated critical habitat.

Additional "take" is likely to be authorized in the future as additional permits are issued as additional permits are issued, along with corresponding ESA consultations for any ESA-listed species affected by the issuance of those permits.

9.12 Impact of the Baseline on Endangered Species Act-Listed Species

Collectively, the stressors described above have had, and likely continue to have, lasting impacts on the ESA-listed marine mammals, sea turtles, and fish in the action area likely to be adversely affected by the proposed action. Some of these stressors result in mortality or serious injury to individual animals (e.g., vessel strikes, incidental bycatch, entanglement), whereas others result in more indirect (e.g., fishing that impacts prey availability) or non-lethal (e.g., whale watching) impacts.

We consider the best indicator of the environmental baseline on ESA-listed resources to be the status and trends of those species. As noted in Section 8, some of the species considered in this consultation are experiencing increases in population abundance, some are declining, and for others, their status remains unknown. Taken together, this indicates that the environmental baseline is impacting species in different ways. The species experiencing increasing population abundances are doing so despite the potential negative impacts of the activities described of the environmental baseline. Therefore, while the environmental baseline may slow their recovery, recovery is not being prevented. For the species that may be declining in abundance, it is possible that the suite of conditions described in this *Environmental Baseline* section is limiting their recovery. However, it is also possible that their populations are at such low levels (e.g., due to historical commercial whaling) that even when the species' primary threats are removed, the species may not be able to achieve recovery. At small population sizes, species may experience phenomena such as demographic stochasticity, inbreeding depression, and Allee effects, among others, that cause their limited population size to become a threat in and of itself. A thorough review of the status and trends of each species for which NMFS has found the action is likely to cause adverse effects is discussed in the *Status of Species Likely to be Adversely Affected* section of this opinion.

10 Effects of the Action

Section 7 regulations define "effects of the action" as all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur (50 C.F.R. §402.02). Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action (see 50 C.F.R. §402.17).

This effects analyses section is organized following the stressor, exposure, response, risk assessment framework.

10.1 Definition of Take, Harm, and Harass

Section 3 of the ESA defines take as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct. We categorize two forms of take, lethal and sublethal take. Lethal take is expected to result in immediate, imminent, or delayed but likely mortality. Sublethal take is when effects of the action are below the level expected to cause death, but are still expected to cause injury, harm, or harassment. Harm, as defined by regulation (50 C.F.R. §222.102), includes acts that actually kill or injure wildlife and acts that may cause significant habitat modification or degradation that actually kill or injure fish or wildlife by significantly impairing essential behavioral patterns, including, breeding, spawning, rearing, migrating, feeding, or sheltering. Thus, for sublethal take we are concerned with harm that does not result in mortality but is still likely to injure an animal.

NMFS has not defined "harass" under the ESA by regulation. However, on October 21, 2016, NMFS issued interim guidance on the term "harass," defining it as to "create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering." For this consultation, we rely on this definition of harass when assessing effects to all ESA-listed species except marine mammals.

Our October 21, 2016, guidance states that our "interim ESA harass interpretation does not specifically equate to MMPA Level A or Level B harassment, but shares some similarities with both levels in the use of the terms 'injury/injure' and a focus on a disruption of behavior patterns. NMFS has not defined 'injure' for purposes of interpreting Level A and Level B harassment but in practice has applied a physical test for Level A harassment." Under the MMPA, harassment is defined as any act of pursuit, torment, or annoyance which:

- Has the potential to injure a marine mammal or marine mammal stock in the wild (Level A Harassment); or
- Has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering (Level B Harassment).

In the following sections, we consider the exposures that could cause an effect on ESA-listed species that are likely to co-occur with the acoustic stressors we have determined are likely to adversely affect these species in space and time, and identify the nature of that co-occurrence. We consider the frequency and intensity of exposures that could cause an effect on ESA-listed species and, as possible, the number, age or life stage, and gender of the individuals likely to be exposed to the action's effects and the population(s) or subpopulation(s) those individuals represent. We also consider the responses of ESA-listed species to exposures and the potential reduction in fitness associated with these responses.

10.2 L-DEO Exposure Analysis

The L-DEO exposure analysis relies on two basic components: (1) information on species distribution (i.e., density within the action area), and (2) information on the level of exposure to sound at which species are likely to be affected (i.e., exhibit some response). In many cases, estimating the potential exposure of animals to anthropogenic stressors is difficult due to limited information on animal density estimates in the action area and overall abundance, the temporal and spatial location of animals; and proximity to and duration of exposure to the sound source. For these reasons, we evaluate the best available data and information in order to reduce the level of uncertainty in making our final exposure estimates.

10.2.1.1 Ensonified Area

In 2003, empirical data concerning 190, 180, and 160 dB re: 1 μPa (rms) distances were acquired during the acoustic calibration study of the R/V *Maurice Ewing*'s airgun array in a variety of configurations in the northern Gulf of Mexico (Tolstoy 2004). At the time, these sound levels represented Level A harassment threshold for pinnipeds and cetaceans, and Level B harassment threshold for marine mammals. In addition, propagation measurements of pulses from the R/V *Marcus G. Langseth*'s 36 airgun array at a tow depth of 6 meters (19.7 feet) have been reported in deep water (approximately 1,600 meters [5,249.3 feet]), intermediate water depth on the slope (approximately 600 to 1,100 meters [1,968.5 to 3,608.9 feet]), and shallow water (approximately 50 meters [164 feet]) in the Gulf of Mexico in 2007 through 2008 (Tolstoy et al. 2009; Diebold et al. 2010). Results of the propagation measurements (Tolstoy et al. 2009) showed that radii around the airguns for various received levels varied with water depth. However, the depth of the airgun array was different in the Gulf of Mexico calibration study 6 meters [19.7 feet]) from in the proposed seismic survey activities (10 to 12 meters [32.8 to 39.4 feet]). Because propagation varies with airgun array depth, correction factors have been applied to the distances reported by Tolstoy et al. (2009).

For deep and intermediate water depth cases, the field measurements in the Gulf of Mexico cannot be used readily to derive MMPA Level A and Level B harassment isopleths, as at those sites the calibration hydrophone was located at a roughly constant depth of 350 to 500 meters (1,148.3 to 1,640.4 feet), which may not intersect all the sound pressure level isopleths at their widest point from the sea surface down to the maximum relevant water depth for marine mammals of approximately 2,000 meters (6,561.7 feet). At short ranges, where the direct arrivals dominate and the effects of seafloor interactions are minimal, the data recorded at the deep and slope sites are suitable for comparison with modeled levels at the depth of the calibration hydrophone. At longer ranges, the comparison with the model, constructed from the maximum sound pressure level through the entire water column at varying distances from the airgun array, is the most relevant.

In deep and intermediate water depths, comparisons at short ranges between sound levels for direct arrivals recorded by the calibration hydrophone and model results from the same airgun array tow depth are in good agreement. Consequently, isopleths falling within this domain can be predicted reliably by the L-DEO model, although they may be imperfectly sampled by measurements recorded at a single depth. At greater distances, the calibration data show that seafloor-reflected and sub-seafloor-refracted arrivals dominate, whereas the direct arrivals become weak and/or incoherent. Aside from local topography effects, the region around the critical distance is where the observed levels rise closest to the model curve. However, the observed sound levels are found to fall almost entirely below the model curve. Thus, analysis of the Gulf of Mexico calibration measurements demonstrates that although simple, the L-DEO model is a robust tool for conservatively estimating isopleths. For deep water depths (greater than 1,000 meters [3,280.8 feet]), L-DEO used the deep water radii obtained from model results down to a maximum water depth of 2,000 meters (6,561.7 feet).

For shallow and intermediate depth waters, L-DEO was able to use site-specific data to calculate the 160 dB and 175 dB re: 1 μPa (rms) isopleths, based on Crone et al. (2014) Crone et al. (2014), empirical data collected on the Cascadia Margin in 2012.

To estimate 160 dB and 175 dB radii in shallow and intermediate water depths, L-DEO used the received levels from multichannel seismic data collected by the research vessel *Marcus G. Langseth* during the 2012 Cascadia Margin survey (Crone et al. 2014), which occurred in the same general area as the proposed 2021 Cascadia Survey. Streamer data in shallow water collected in 2012 have the advantage of including the effects of local and complex subsurface geology, seafloor topography and water column properties and thus allow us to establish mitigation radii more confidently than by using the data from calibration experiments in the Gulf of Mexico (Tolstoy 2004; Tolstoy et al. 2009; Diebold et al. 2010).

10.2.1.2 Exposure Estimates of Endangered Species Act-Listed Marine Mammals

As discussed in the *Status of Species Likely to be Adversely Affected* section, there are eight ESA-listed marine mammal species that are likely to be adversely affected by the proposed action: blue, fin, Central America DPS of humpback, Mexico DPS of humpback, sei, sperm, Southern Resident killer whales and Guadalupe fur seals.

During the proposed action, ESA-listed marine mammals may be exposed to sound from five sound sources: the airgun array, multi-beam echosounder, sub-bottom profiler, acoustic Doppler current profiler, and acoustic release transponder.

Where available, the appropriate seasonal density estimate from the U.S. Navy Marine Species Density Database or CetSound was used in the exposure estimates (i.e., summer). For species with a quantitative density range within or around the action area, the maximum presented density was conservatively used. The approach used here is based on the best available data.

Table 43. Densities used for calculating exposure of ESA-listed cetaceans.

Species	Density (#/km^2) in Shallow Water (< 100 meters)	Density (#/km^2) in Intermediate Water (100 to 1,000 meters)	Density (#/km^2) in Deep Water (> 1,000 meters)	Source
Humpback Whale	0.005420	0.004020	0.000483	(Becker et al. 2016)
Blue Whale	0.002023	0.001052	0.000358	(Becker et al. 2016)
Fin Whale	0.000202	0.000931	0.001381	(Becker et al. 2016)
Sei Whale	0.000400	0.000400	0.000400	(Navy 2019)
Sperm Whale	0.0000586	0.0001560	0.0013023	(Becker et al. 2016)

Densities for Guadalupe fur seals were available within the 200-meter isobath (0.015300 #/km^2) and from the 200-meter isobath to 300 kilometers offshore (0.017100 #/km^2) in summer (Navy 2019). The Permits Division used habitat-based density model data obtained from the Navy (Navy 2019) to calculate the exposure estimates for Southern Resident killer whales using GIS. Density estimates for Southern Resident killer whales from the U.S. Navy's Marine Species Density Database (Navy 2019) were overlaid with GIS layers of the Level B harassment zones in each depth category to determine the areas expected to be ensonified in each density category and to calculate exposure numbers (Figure 44; see Table 46 for the key and colors depicting the densities and the amount of ensonified area in each density area).

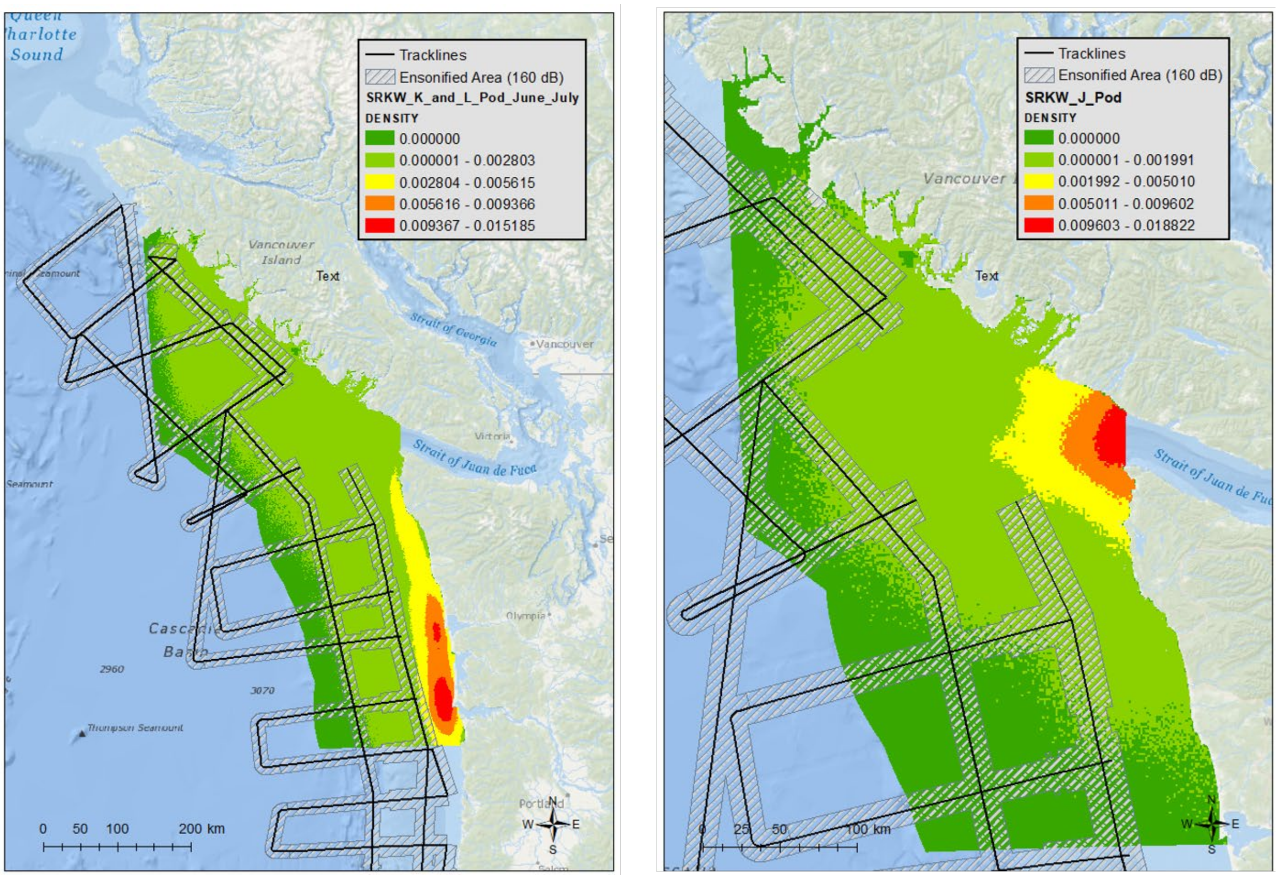

Figure 43. Map of expected densities of Southern Resident killer whales overlaid with the survey tracklines and ensonified area.

Table 44. Southern Resident killer whale densities key.

Pod	Density (animals/km^2)	Ensonified Area (km^2)	Color Key
	0.000000	5,888	Dark Green
	0.000001 - 0.002803	15,470	Light Green
K/L	0.002804 - 0.005615	342	Yellow
	0.005616 - 0.009366	0	Orange
	0.009367 - 0.015185	0	Red
J	0.000000	6,427	Dark Green

Pod	Density (animals/km^2)	Ensonified Area (km^2)	Color Key
	0.000001 - 0.001991	5,556	Light Green
	0.001992 - 0.005010	0	Yellow
	0.005011 - 0.009602	0	Orange
	0.009603 - 0.018822	0	Red

In addition to the density information in this section, we also present information on ESA-listed marine mammals in the action area to describe additional details on the nature of the exposure.

Fin, Sei, Blue and Sperm Whales

Blue, fin, and sei whale habitat in Canadian Pacific waters typically includes the continental shelf break, continental slope, and oceanic waters beyond the shelf break (Canada 2017). According to an analysis of historic whaling records, fin, sei, and male sperm whales occurred in summer along the shelf break of the coastal waters of British Columbia, extending over a large area 75 to 100 kilometers beyond the shelf at the north end of Vancouver. When the action takes place in these areas, we consider it more likely that fin, sei, and male sperm whales would be exposed at that time than they would in other areas. Male sperm whales were more closely associated with the shelf break than females, who appear to distribute much more diffusely throughout the area. (Gregr and Trites 2001). In June and July, we would expect blue whales in the area to be foraging or traveling, likely following the phytoplankton bloom (e.g., for foraging opportunities) (Abrahms et al. 2019). The waters off Vancouver are highly productive and serve as a secondary foraging area for blue whales; blue whales generally move north through Oregon and Washington waters to forage off Vancouver (Burtenshaw et al. 2004b). Blue whales that are exposed to the proposed action off Washington or Oregon would likely be traveling to foraging areas, while those that are exposed off Vancouver would likely be foraging.

Humpback Whales

Individual humpback whales from the Central America, Mexico, and Hawaii DPSs could be present in the action area during the seismic survey. There are two feeding areas in the action area—California/Oregon, and Washington/Southern British Columbia—where we expect humpback whales to be exposed. Individuals from Hawaii are thought to mostly feed in feeding areas from the Aleutian Islands, Alaska, to British Columbia (Ford 2009). There are more individuals from the Mexico and Central America DPSs on the California/Oregon and Washington/Southern British Columbia feeding areas (Wade 2017). The humpback whales we expect to be exposed in the action area are comprised of multiple distinct population segments: Hawaii, Central America, and Mexico. We do not expect individual humpbacks from the ESA-endangered Western North Pacific DPS to be present in the action area, and it will not be considered.

Based on Wade (2017) and the NMFS guidance, we expect that there will be different proportions of the three DPSs present in each of the summer feeding areas. As such, we need to evaluate the proportion of the action area that will occur in each of the summer feeding areas.

Since the proposed action will take place over two feeding areas, we need to determine how humpback whales we expect to occur throughout each of the feeding areas in the action area.

The total survey will cover about 6,540 kilometers of tracklines. The number of tracklines off the coast of Oregon, and presumably those that would occur in the Oregon and California feeding area is 3,207.4 kilometers (49 percent). The number of tracklines in the Southern British Columbia/Washington feeding area is approximately 3,346.9 kilometers (51 percent). By applying these percentages to the total amount of expected number of humpback exposure, we estimated that 72 individual humpbacks would be in British Columbia/Washington feeding area, and 68 individuals in the Oregon area (140 individuals total due to rounding). We then applied the percentages presented in Table 47 to determine the number of individuals from each distinct population segment exposed to the proposed action.

Table 45. Probability of encountering humpback whales from each distinct population segment in the North Pacific Ocean in various summer feeding areas. Adapted from Wade (2017).

Summer Feeding Areas	Western North Pacific Distinct Population Segment	Hawaii Distinct Population Segment	Mexico Distinct Population Segment	Central America Distinct Population Segment
Kamchatka	100%	0%	0%	0%
Aleutian Islands, Bering Sea, Chukchi Sea, Beaufort Sea	2.1%	86.8%	11%	0%
Gulf of Alaska	0.4%	87.2%	12%	0%
Southeast Alaska, Northern British Columbia	0%	96.1%	3.8%	0%
Southern British Columbia, Washington	0%	63.5%	27.9%	8.7%
Oregon, California	0%	0%	32.7%	67.2%

For the Oregon/California feeding area, we estimate that 68 humpback whales would be exposed. By applying the Wade (2017) proportions (Mexico DPS 32.7 percent; Central America DPS 67.2 percent; Hawaii 0 percent), we estimate that the number of individuals from each DPS exposed would be:

- 23 Mexico DPS individuals and
- 47 Central America DPS individuals.

For the British Columbia/Washington feeding area, we estimate that 72 humpback whales would be exposed. By applying the Wade (2017) proportions (Mexico DPS 27.9 percent; Central America DPS 8.7 percent; Hawaii 63.5 percent), we estimate that the number of individuals from each DPS exposed would be:

- 45 Hawaii DPS individuals,
- 20 Mexico DPS individuals, and
- 6 Central America DPS individuals.

The total number of humpback whales exposed for the survey would be:

- Hawaii DPS: 45
- Mexico DPS: 43
- Central America DPS: 53

Only the Mexico and Central America DPSs are listed under the ESA, so we expect 96 total exposures for ESA-listed humpback whales (excluding the 45 exposures for the non-listed Hawaii DPS). We expect all life stages and both sexes to be exposed to the proposed action, and that individuals would be exposed while foraging or traveling to or from feeding areas.

Southern Resident Killer Whales

Based on the available information, we do believe that Southern Resident killer whales will be exposed. The proposed seismic activities will take place starting on June 1, 2021, and last for 37 days, ending on or about July 7, 2021. It is difficult to predict with any degree of certainty where precisely Southern Resident killer whales will be during the seismic survey. Southern Resident killer whale occurrence is believed to be largely driven by prey availability, particularly Chinook salmon.

In summer, Southern Resident killer whales have traditionally occurred with regularity in the inland waters of Washington and British Columbia (e.g., the Strait of Juan de Fuca, Haro Strait, Boundary Pass, Georgia Strait; (Hauser et al. 2007). Because the proposed seismic activities take place in June and into July, one might expect the Southern Resident killer whales to be in the inland waters of Washington and British Columbia, and thus away from the survey and not exposed to the action. Indeed, reports from whale-watching networks regularly document killer whales in the Salish Sea in June and July each year[15], and numerous scientific publications support this area as making up the summertime range of Southern Residents. These observations and studies were the basis for designating the inland waters of Washington as critical habitat for the distinct population segment in 2006.

However, these data, observations, and studies only account for less than half the days of the year, and until relatively recently, there was little known about the population's distribution throughout the year outside of these inland water areas. In the Southern Resident Killer Whale Recovery Plan, there was an emphasis placed on filling this data gap (NMFS 2008d). In order to better understand Southern Residents' outer coastal range, passive acoustic monitoring stations were established off the outer coasts of Washington, Oregon, and California, as well as increased satellite-tagging efforts for Southern Resident killer whales.

For this consultation, we cannot rely on a generalization about Southern Resident killer whale summer range as outside the action area. An examination of Southern Resident killer whale occurrence in spring (April 1 to June 30) over the years 1994 to 2016 showed a decline in habitat use in the Salish Sea in spring (Shields et al. 2018). The Fraser River spring run Chinook experienced a decline in 2005, and Shields et al. (2018) observed that Southern Resident killer whales spent fewer days in the Salish Sea after that time (62.2 days on average from 1994 to 2004, versus 47.75 days from 2005 to 2016). The shift in habitat use is thought to be related to the presence (or absence) of Chinook salmon in the Salish Sea, namely Fraser River Chinook salmon. In the past (2004 to 2008), Southern Resident killer whales preyed mostly upon Chinook salmon from the Fraser River while in the Strait of Juan de Fuca and around the San Juan Islands in summer months (Hanson et al. 2010a). It is possible that the Southern Resident killer whales are changing their habitat use in order to find adequate prey. In addition to the information presented above, reports from local media and killer whale sighting networks indicate that Southern Resident killer whales are much less prevalent or even conspicuously absent from their expected summer range in the Salish Sea in the last few years.[16] [17]

Acoustic monitoring efforts have indicated that waters outside the inland waters of the Salish Sea are used by the Southern Resident killer whales to a significant degree. Acoustic monitoring stations at Swiftsure Bank, off the southern coast of Vancouver Island, detected Southern Resident killer whales every month of the year between 2009 and 2011, with a peak in summer months (June, July, and August) (Riera et al. 2019). All three pods were detected at least once in every month with a few exceptions. J pod was not detected in January or November, and L pod was not detected in March (Riera et al. 2019). K and L pods were frequently detected together,

[15] http://www.orcanetwork.org/Archives/index.php?categories_file=Sightings%20Archives%20Home (Accessed 2/17/2021).
[16] https://www.seattletimes.com/seattle-news/environment/where-are-the-southern-resident-orcas-researchers-see-longest-absence-ever-from-summer-waters/ (Accessed 2/17/2021)
[17] http://www.orcanetwork.org/Archives/index.php?categories_file=Sightings%20Archive%20-%20Jul%2019 (Accessed 2/17/2021)

with the longest encounter durations occurring in May through September. At an acoustic monitoring station at Cape Elizabeth, Washington, on the edge of the continental shelf, Southern Resident killer whales were detected in January through June, and in October (Rice et al. 2017).

Through passive acoustic monitoring, Southern Resident killer whales were detected in every month from January to June off the outer coast of Cape Flattery, Washington. Detection rates of Southern Resident killer whales in coastal waters from Cape Flattery, Washington, to Point Reyes, California, were greater in 2009 to 2011 than in 2006 to 2008 (Hanson et al. 2013). J pod individuals were only detected on the northern-most recorders (near Cape Flattery), and then only infrequently. K and L pods were also detected off California in January, February, May, and December (Hanson et al. 2013; NMFS 2019c).

We cannot say with certainty where precisely we expect Southern Resident killer whales to be at the time of the proposed survey, but based on the available studies and acoustic data, Navy density data, and sightings reports, we cannot assume that the Southern Residents will definitely be in the inland waters of Washington and British Columbia during the proposed action. It is possible that the Southern Resident killer whales could be exposed to the proposed action if they are foraging in the coastal waters within the action area (see Figure 44).

Based on satellite tagging, acoustic recording data, and opportunistic sightings, Southern Resident killer whales spend most (96.5 percent) of their time on the continental shelf, within 34 kilometers of shore in waters less than 200 meters deep (NMFS 2019c). Five percent of locations were within two kilometers of shore, and five percent beyond 34 kilometers. 77.7 percent of satellite tag locations occurred in waters less than 100 meters deep, and only 5.3 percent were in waters less than 18 meters deep (NMFS 2019c). High-use areas included the Washington outer coast, (53.1 percent of their time spent there), and about 19 percent between Grays Harbor (southern Washington) and the Columbia River (i.e., the Oregon/Washington border) (NMFS 2019c). When the seismic survey is occurring in these areas, we expect the likelihood of exposure to be greater.

We would expect individuals of all age classes and both sexes to be exposed, from each of the three pods.

The Permits and Conservation Division used Navy density data (Navy 2019) and GIS to calculate the number of Southern Resident killer whale exposure during the proposed action. The Navy density data is depicted in Figure 44 and Table 46. Because individuals from K and L pods tend to travel together, with J pod traveling as a group, this led the Navy to calculate densities for J pod separately, and K and L pods together (Riera et al. 2019). The total number of exposures and exposures by pod are presented in Table 48 below.

Table 46. Modelled exposures for Southern Resident killer whales.

Southern Resident Killer Whale Pod	Number of Exposures
K and L Pod	9
J Pod	2
Total for the DPS	**11**

The modelled exposures are for Southern Resident killer whales throughout the entire action area, in the U.S. EEZ and the territorial waters of Canada.

Guadalupe Fur Seals

Guadalupe fur seals strand almost annually in California, and are observed in increasing numbers in Oregon and Washington (Carretta 2019a). The current Unusual Mortality Event for Guadalupe fur seals is ongoing; in 2019, over 90 Guadalupe fur seal pups and juveniles have stranded in Oregon and Washington.[18] In June, adult males and females arrive at their colonies to breed and pup; breeding colonies for the species are on Guadalupe Island and San Benito Island, Mexico, with a purported breeding colony on San Miguel Island, of the Channel Islands, California, all far outside the action area.

With the population increasing, the broad range of the species at sea, and strandings in the area, we do expect Guadalupe fur seals to be in the action area and be exposed to the proposed action. Because the seismic activities take place in June and July, during breeding and pupping season, we do not think adult Guadalupe fur seals would be exposed to the proposed action. Based on strandings in the area, we expect that juveniles and pups of both sexes would be exposed to the proposed action. These stranded animals are showing signs of malnutrition with secondary bacterial and parasitic infections, so it is possible that exposed Guadalupe fur seals would already be compromised when exposed to the seismic activities.

Exposure Summary

To summarize, the number of ESA-listed marine mammals exposed to the proposed seismic activities are presented in Table 49.

[18] https://www.fisheries.noaa.gov/national/marine-life-distress/2015-2019-guadalupe-fur-seal-unusual-mortality-event-california (Accessed 3/8/2021)

Table 47. Number of total exposures of ESA-listed marine mammals in the entire action area during National Science Foundation's seismic survey in the Northeast Pacific Ocean.

Species	Total Number of Exposures
Blue Whale	59
Fin Whale	97
Humpback Whale – Central America DPS	53
Humpback Whale – Mexico DPS	43
Sei Whale	33
Sperm Whale	73
Killer whale—Southern Resident DPS	11
Guadalupe Fur Seal	2,161

As discussed in Section 4.1, parts of the action area take place in the territorial waters of Canada, and we are not able to authorize take in those waters. However, we must estimate the amount of ESA-listed species that could be exposed throughout the entire action area in making our jeopardy determination; in this case, that means the entire ensonified area for the proposed action.

The NSF and the L-DEO provided exposure estimates both inside and outside Canadian territorial waters, representing all potential exposures no matter where they might occur. Those estimates are presented in Table 49.

10.2.1.3 Exposure Estimates of Endangered Species Act-Listed Sea Turtles

As discussed in the *Status of Species Likely to be Adversely Affected* section, there is one ESA-listed sea turtle species that is likely to be affected by the proposed action: leatherback turtles.

During the proposed action, ESA-listed sea turtles may be exposed to sound from five sound sources: the airgun array, multi-beam echosounder, sub-bottom profiler, acoustic Doppler current profiler, and acoustic release transponder.

Density Estimates and Modeled Exposure

The L-DEO used a similar method to calculate exposure for leatherback sea turtles as that for marine mammals. In the case of leatherback sea turtles, the L-DEO used the 175 dB threshold to create a buffer in GIS representing the ensonified area within each of the three water depth categories (< 100 meters, 100 to 1000 meters, and >1000 meters). The L-DEO used density estimates from (Navy 2019) (0.000114 #/km^2) to obtain an estimated 3 leatherback sea turtles exposed. The modeled exposures are all expected to occur outside Canadian territorial waters (and elsewhere throughout the action area) because leatherback sea turtles forage in deeper waters (200 meters deep or more), and these waters are beyond the 12 nautical mile line of Canadian territorial waters.

In U.S. Pacific waters, leatherbacks forage in shelf waters between the 200-meter and 2,000-meter isobaths (77 FR 4169). An examination of 122 opportunistic sightings of leatherback sea turtles in Canadian Pacific waters, most of them were in waters from the continental shelf to 200 meters deep, with fewer in waters 1,500 meters deep and offshore waters (Gregr 2015). There is considerable bias associated with these sightings as they were not part of a systemic survey, but they do allow us to reasonably believe that leatherback sea turtles are likely to be exposed to seismic activities during the proposed action. Depth is considered a factor in leatherback sea turtle occurrence in the Canadian Pacific, as there is evidence that indicates they preferentially forage in on-shelf areas; sea surface temperature is also an important factor in predicting occurrence (with a potential thermal limit of 13 degrees Celsius) (Benson et al. 2011a; Gregr 2015).

Leatherback sea turtles arrive on foraging grounds off the U.S. West Coast primarily in April through July (Benson et al. 2011a). The majority of sightings in the Canadian Pacific are between July and September (Gregr 2015). Because of the timing and location of the action, we expect that the three exposed leatherback sea turtles would be foraging or transiting to foraging areas at the time of the action. Adults of both sexes could be exposed to the proposed action.

10.2.1.4 Exposure Estimates of Endangered Species Act-Listed Fishes

As discussed in the *Status of Species Likely to be Adversely Affected* section, there are seven ESA-listed fish species that are likely to be adversely affected by the proposed action: Southern DPS green sturgeon, southern DPS eulachon, ESA-listed ESUs or DPSs of Chinook, Coho, chum, sockeye, and steelhead (Table 5).

During the proposed action, ESA-listed fishes may be exposed to sound from five sound sources: the airgun array, multi-beam echosounder, sub-bottom profiler, acoustic Doppler current profiler, and acoustic release transponder. The National Science Foundation, L-DEO, and NMFS Permits and Conservation Division did not provide estimates of the expected number of ESA-listed fishes in the area of these sound sources.

Salmonid Presence in the Marine Environment

The seismic survey will take place over a broad range of ocean habitats, from the nearshore, shallow waters off the coasts of Oregon, Washington, and Vancouver, the continental shelf, the continental slope, and the offshore oceanic area beyond the slope. This action area will encompass a variety of habitats for ESA-listed species, and different habitats are more likely to host one species or another based its habitat requirements. For the ESA-listed fish species considered in this consultation, the continental shelf is a very important habitat. The continental shelf off the U.S. West Coast is the area from the intertidal zone to the 200 meter depth contour

(656 feet), which is typically 8 to 60 kilometers from shore (NMFS 2015d). The survey tracklines come close to shore, as close as about 14 kilometers in some places, and the furthest tracklines are over 300 kilometers from shore.

The total number of tracklines proposed for the survey is about 6,540 kilometers. About 1,964 kilometers will take place in waters less than 200 meters deep in the waters of the continental shelf (30 percent of the total survey).

The survey will take place starting in June, and last for 37 days. The timing and location of the survey means that ESA-listed fishes of different life stages will be exposed. The overall amount of tracklines over the continental shelf (less than 200 meters deep) is 1,964 kilometers, and it would take the R/V *Marcus G. Langseth* approximately 252 hours, or about 10.5 days, to complete seismic activities on those lines. This is a relatively short amount of time over which ESA-listed Chinook (and other salmonids) could be exposed. The survey would collect data on the tracklines in those areas, and then move on to other parts of the action area, meaning that the duration of exposure would be limited. In total, there will be about 11,150 km^2 of ensonified area (to the TTS threshold for fish) occurring in continental shelf waters. This amounts to approximately 11.8 percent of the entire survey. The tracklines in waters less than 200 meters deep are spread out over the entire survey area, with more occurring off of northern Vancouver and Oregon than Washington (due to the revisions to lines in those areas, see Figure 3).

The tracklines were revised to avoid areas off Washington and Vancouver due to concerns over exposure of Southern Resident killer whales, where they could be foraging primarily on Chinook salmon, if they were in coastal areas during the time of the proposed action. Coastal Washington waters and the La Perouse and Swiftsure banks off Vancouver are relatively shallow, and considered very productive for Chinook and other salmonids (Healey et al. 1990; Peterson et al. 2010). By avoiding these areas to reduce exposure of Southern Resident killer whales that may be foraging there, the proposed action would also avoid these areas where Chinook and other salmonids occur, reducing exposure of those species. In the places where the tracklines will be in continental shelf waters less than 200 meters deep, like northern Vancouver and coastal Oregon, we do not expect high densities of Southern Resident killer whales (see Figure 44) (Navy 2019).

Salmonids

There are several ESA-listed DPSs or ESUs of Pacific salmonids that could occur in the action area during their oceanic life phase, including:

- Snake River Spring/Summer Run ESU of Chinook salmon,
- Snake River Fall Run ESU of Chinook salmon,
- California Coastal ESU of Chinook salmon,
- Central Valley Spring Run ESU of Chinook salmon,
- Sacramento River Winter Run ESU of Chinook salmon,
- Lower Columbia River ESU of Chinook salmon,
- Puget Sound ESU of Chinook salmon,
- Upper Willamette River ESU of Chinook salmon,

- Upper Columbia River Spring Run ESU of Chinook salmon,
- Columbia River ESU of chum salmon,
- Hood Canal Summer Run of chum salmon,
- Central California Coast ESU of Coho salmon,
- Lower Columbia River ESU of Coho salmon,
- Oregon Coast ESU of Coho salmon,
- Southern Oregon Coast ESU of Coho salmon,
- Ozette Lake ESU of sockeye salmon,
- Snake River ESU of sockeye salmon,
- Lower Columbia River DPS of steelhead trout,
- Middle Columbia River DPS of steelhead trout,
- Puget Sound DPS of steelhead trout,
- Snake River DPS of steelhead trout,
- Snake River Basin DPS of steelhead trout,
- Northern California DPS of steelhead trout,
- California Central Valley DPS of steelhead trout,
- Central California Coast DPS of steelhead trout,
- South-Central California Coast DPS of steelhead trout,
- Upper Columbia River DPS of steelhead trout, and
- Upper Willamette River DPS of steelhead trout

There is some uncertainty about precisely where in the Pacific Ocean these (or any) salmonids go (Meyers 1998); based on what we do understand, however, the DPSs or ESUs noted above are likely to be present, because salmon form mixed stock aggregations during their time in the ocean (Bellinger et al. 2015). The following sections will discuss the life stages likely to be exposed and the distributions of the Pacific salmon and steelhead DPSs or ESUs in relation to the proposed action area.

Salmon Life Stages Present

Due to the timing and location of the proposed seismic survey, we expect both juvenile and adult salmon and steelhead to be exposed to the action. The marine environment represents very important habitat for salmon and steelhead during critical phases of their life cycle. This includes:

- Juveniles when they are entering the marine environment from their natal rivers,
- Juveniles already in the marine environment for their growth phase, and
- Pre-spawning adults that are returning to their natal rivers to spawn.

While not every population of Pacific salmon and steelhead may be exposed during their entry into the ocean or during their spawning run due to the location and timing of the proposed action, we still expect them to be exposed while in the marine environment. Pacific salmonids spend a few years in the ocean during their growth phase, and could be exposed to the proposed seismic activities then.

Estuaries represent important habitat for both juvenile and adult salmon. Adults use coastal areas near their natal rivers as staging areas before moving into freshwater to spawn. Residence times for adults in staging areas can vary from one to six weeks. Juveniles can remain in the estuaries for four days (chum) to up to six months (Chinook) before entering the marine environment (Simenstad et al. 1982), likely using the areas to adjust to higher salinity water. Where the action area overlaps with the staging areas for various salmon populations, both juveniles and adults could be exposed. In some areas, especially at the southern end of the survey near Oregon where the tracklines are close to shore, sound from the seismic airguns could enter estuaries and coastal areas where salmon are staging.

In order to be exposed to the proposed action when entering the marine environment, the juvenile salmon or steelhead must be exiting from a river that is in the action area (or drains into a river system in the action area, i.e., the Snake River). For this action, that would include rivers in Oregon and Washington. Juveniles entering the ocean from rivers in California would not be exposed at that time of entry. However, juveniles from rivers south of the action area may still be exposed to the proposed seismic activities in the marine environment since juvenile salmon and steelhead form mixed stock aggregations there. In addition, juvenile salmon and steelhead may also be exposed after they enter the marine environment during their migration to their preferred marine growth location. For example, juvenile sockeye enter the ocean and use coastal waters to migrate northward to southeast Alaska, and juvenile chum move northward to the Gulf of Alaska.

The specific spawning migration and entry timing varies by species and distinct population segment or evolutionarily significant unit. See the tables below for information on migration timing by species. Here, we refer to adult salmonids present in their natal rivers and moving upriver to spawn as "adult spawning migration timing" and juveniles leaving their natal rivers to enter the ocean for their growth phase as "juvenile entry into marine environment".

As discussed earlier, Pacific salmonids form mixed stock aggregations in the marine environment. In the case of Chinook salmon, individuals from a broad area are found in the coastal waters of the action area.

In a fishery-dependent study from May to September in the coastal waters of Oregon and northern California, Bellinger et al. (2015) identified Chinook salmon from numerous river systems from Alaska to the Central Valley, California. Stock richness was highest in the northern part of the sampling area than in the south. In a study of killer whale prey collection from off the coasts of Oregon and Washington, Chinook from a broad area were found in fecal samples, including fish from the Middle Fraser River, Canada, Puget Sound, Washington, the Columbia River, Oregon and Washington, the Snake River, Washington and Idaho, the Klamath River, California, the Central Valley (Sacramento and San Joaquin Rivers), California, and the Taku River in southeast Alaska (NMFS 2019c).

Based on this information, we are examining Chinook salmon distinct population segments or evolutionarily significant units from a broad area. The timing of their spawning runs and entry into the ocean are shown in Table 52.

Table 48. Spawning Migration and Entry Timing for Chinook Salmon Distinct Population Segments/Evolutionarily Significant Units

Chinook Distinct Population Segment/Evolutionarily Significant Unit	Chinook Adult Spawning Migration Timing	Chinook Juvenile Entry into Marine Environment
Puget Sound	April to May: Spring-run June to July: Summer-run Fall-run: August to September (Myers 1998)	Spring-run: May to June Summer and fall-run: April to July (Myers 1998)

Chinook Distinct Population Segment/Evolutionarily Significant Unit	Chinook Adult Spawning Migration Timing	Chinook Juvenile Entry into Marine Environment
Upper Columbia River Spring Run	Late March to May, peak in mid-May.	April to June; Peak numbers in May. All enter Canadian waters by end of June. (Myers 1998; Fisher et al. 2014a)
Lower Columbia River	March to June: Spring-run August to October: Fall-run	March to September (Peak numbers April to June): Spring-run March to September (Peak numbers in September): Fall-run (Fisher et al. 2014a)
Upper Willamette River	February to August, peak from April to late May. (Myers 1998)	March to September, peak numbers in June. (Myers 1998; Fisher et al. 2014a)
Snake River Spring-Summer	March to May. Spawning adults present along the Washington Coast and Columbia River plume. Peak numbers in May. (DART 2013)	April to June, peak numbers in May. All entering Canadian waters by June. (Myers 1998; Fisher et al. 2014a)
Snake River Fall Run	August to October: Spawning adults present along the Washington Coast and Columbia River plume (Peak numbers in September).	June to November: No significant peak. All entering Canadian waters by end of November. (Myers 1998; Fisher et al. 2014a)

Chinook Distinct Population Segment/Evolutionarily Significant Unit	Chinook Adult Spawning Migration Timing	Chinook Juvenile Entry into Marine Environment
	(DART 2013)	
California Coastal	September to early November (Moyle et al. 2017)	February to June (Moyle et al. 2017)
Central Valley Spring-Run	March to July (Myers 1998)	February to June, peaks April to May (Cordoleani et al. 2018)
Sacramento River Winter-Run	November to June (Myers 1998; Moyle et al. 2017)	January through May, peaking in mid-March (Moyle et al. 2017)

Adult individuals from DPSs or ESUs that migrate to spawn after July and August would likely be moving to or already in coastal staging areas, in estuaries or in the mouths of rivers within the action area, preparing to move upstream later in the season. These individuals could be exposed to the seismic survey and include:

- Puget Sound ESU, fall run
- Lower Columbia River ESU, fall run
- Snake River Fall Run ESU

The survey would occur in June and into July. The information presented in Table 52 for adult spawning migration timing refers the periods when adults are in their natal rivers, moving upstream to the spawning sites. This information comes from tagging studies recording tagged salmon as they pass upstream. We do not expect individuals from the other adult Chinook salmon distinct population segments or evolutionarily significant units listed in Table 52 to be exposed to seismic activities during their upstream migration.

The seismic survey does not take place in California waters, so it would not expose adult individuals from ESUs originating in California while they were staging in coastal waters. However, since Pacific salmon form mixed stock aggregations in the marine environment, it is possible that adults from the following populations could be exposed while moving through the action area to their natal rivers:

- California Coastal ESU

- Sacramento River Winter-run ESU

We expect individuals from the following juvenile Chinook salmon distinct population segments or evolutionarily significant units to be exposed to seismic activities during their entry into the marine environment in the action area:

- Puget Sound ESU: Summer and fall runs
- Lower Columbia River ESU: Spring and fall runs
- Upper Willamette River ESU
- Snake River Fall-Run ESU

Coho

Coho salmon enter the ocean in spring of their second year, and spend the next few years in the ocean, as they grow from smolts to adults, before the adults return to freshwater to spawn, usually in fall or early winter of their third year (Cole 2000). Spawning migration times and marine entry times for Coho salmon are shown in Table 53.

Table 49. Spawning Migration and Entry Timing for Coho Salmon Distinct Population Segments/Evolutionarily Significant Units

Coho Distinct Population Segment/Evolutionarily Significant Unit	Coho Adult Spawning Migration Timing	Coho Juvenile Entry into Marine Environment
Lower Columbia River ESU	Mid-September to mid-November (Fulton 1970)	March to July (Bell 1990)
Oregon Coast ESU	October to December (Weitkamp et al. 1995)	March to July Bell 1990
Southern Oregon/Northern California ESU	September to October (Weitkamp et al. 1995; Moyle et al. 2017)	March to May (Moyle 2002a)
Central California Coast DPS	November to January (Weitkamp et al. 1995; Moyle et al. 2017)	March to May Moyle 2002

Adult Coho from the Central California distinct population segment or the Southern Oregon/Northern California evolutionarily significant units may be exposed to the proposed action while in the marine environment or while transiting to their natal streams. Adult Lower

Columbia River and Oregon Coast Coho may be exposed while in the marine environment. We do expect the following juvenile Coho to be exposed as they enter the marine environment from their natal rivers:

- Lower Columbia River ESU
- Oregon Coast ESU

Juvenile Coho from any distinct population segment or evolutionarily significant unit may be exposed to the proposed action while in the marine environment.

Chum

Upstream spawning migration times and marine entry times for chum salmon are shown in Table 54.

Table 50. Spawning Migration and Entry Timing for Chum Salmon Evolutionarily Significant Units

Chum Distinct Population Segment/Evolutionarily Significant Unit	Chum Adult Spawning Migration Timing	Chum Juvenile Entry into Marine Environment
Hood Canal Summer-Run ESU	Mid-August to mid-October, peak in September (Johnson et al. 1997b)	February to early April (Tynan 1997)
Columbia River ESU	Early October to mid-November (Johnson et al. 1997b)	March to May Washington Department of Fish and Wildlife, 2019

Adult chum salmon that are in coastal staging areas before entering their natal rivers to spawn. Hood Canal is in Puget Sound, and not in the action area, so adults from the Hood Canal Summer-Run ESU will not be exposed at that time, but could be exposed while in the marine environment transiting into that area. Due to the timing of the entry into the marine environment, we do not expect any juvenile chum salmon to be exposed during those times. Immature and maturing chum salmon are distributed widely throughout the offshore waters of the Gulf of Alaska, outside the action area (Salo 1991a). After entering the ocean, juvenile chum migrate northward from the Columbia River and Hood Canal along the coast until reaching Alaska (Johnson et al. 1997b). Because they enter the marine environment as late as May, juvenile chum could be exposed to the proposed action in June and July while they are traveling north, especially those from the Columbia River, which is within the action area.

Sockeye

Spawning migration times and marine entry times for sockeye salmon are shown in Table 55.

Table 51. Spawning Migration and Entry Timing for Sockeye Salmon Evolutionarily Significant Units

Sockeye Distinct Population Segment/Evolutionarily Significant Unit	Sockeye Adult Spawning Migration Timing	Sockeye Juvenile Entry into Marine Environment
Ozette Lake ESU	Mid-April to mid-August (Peak: May and June) (NMFS 2009c)	March to June (Peak: April and May) (NMFS 2009c)
Snake River ESU	June to July (NMFS 2015c)	May to mid-June (Tucker et al. 2015)

Due to the timing of their spawning runs, we do not expect the adult sockeye Snake River ESU to be exposed to the proposed seismic activities since they are expected to be in the river at the time of the proposed action. Ozette Lake ESU adult sockeye salmon return from the ocean to Lake Ozette from mid-April to mid-August, and thus could be exposed to the proposed action.

Upon leaving the Ozette River and entering the ocean, juveniles undergo a rapid northward migration along the coast to southeast Alaska, arriving by mid-June to July (Tucker et al. 2015). Juveniles from the Columbia River plume undergo a northward similar migration (the Snake River feeds into the Columbia River), but enter the ocean a little later than Ozette Lake sockeye juveniles. By fall, both ESUs are absent from the continental shelf (Gustafson et al. 1997; Tucker et al. 2015). Because the proposed seismic activities will take place in June and July, and the survey will extend all the way to Vancouver Island in the north, we expect migrating juvenile sockeye salmon to be exposed to the proposed action.

Steelhead

Spawning migration times and marine entry times for steelhead are shown in Table 56.

Table 52. Spawning Migration and Entry Timing for Steelhead Evolutionarily Significant Units

Steelhead Distinct Population Segment/Evolutionarily Significant Unit	Steelhead Adult Spawning Migration Timing	Steelhead Juvenile Entry into Marine Environment
Puget Sound DPS	November to Mid-June: Winter-run	March to June Bell 1990

Steelhead Distinct Population Segment/Evolutionarily Significant Unit	Steelhead Adult Spawning Migration Timing	Steelhead Juvenile Entry into Marine Environment
	April to November: Summer-run Bell 1990 (Busby et al. 1996b)	
Upper Columbia River DPS	November to May June to Early August: "A-run" Bell 1990 (Busby et al. 1996b)	Mid-April to Early June (Daly et al. 2014)
Middle Columbia River DPS	November to May June to Early August: "A-run" Bell 1990 (Busby et al. 1996b)	Mid-April to Early June (Daly et al. 2014)
Lower Columbia River DPS	Late February to Early June: Spring-run November to May: Winter-run Bell 1990 (Busby et al. 1996b)	Mid-April to Early June (Daly et al. 2014)
Upper Willamette River DPS	February to March: Late winter-run (Busby et al. 1996b)	Mid-April to Early June (Daly et al. 2014)
Snake River Basin DPS	June to Early August: "A-run" August to October: "B-run" Bell 1990 (Busby et al. 1996b)	Mid-April to Early June (Daly et al. 2014)

Steelhead Distinct Population Segment/Evolutionarily Significant Unit	Steelhead Adult Spawning Migration Timing	Steelhead Juvenile Entry into Marine Environment
Northern California Coast DPS	March to August: Summer-run September to November: Winter-run (Busby et al. 1996b; Moyle et al. 2017)	March to June (Moyle et al. 2017)
California Central Valley DPS	August to October (Busby et al. 1996b; Moyle et al. 2017)	March to May Busby et al. 1996; Moyle et al. 2017 (Moyle et al. 2017)
Central California Coast DPS	October to November (Busby et al. 1996b; Moyle et al. 2017)	January to June Busby et al. 1996; Moyle et al. 2017 (Moyle et al. 2017)
South-Central California DPS	January to May (Moyle et al. 2017)	January to May (Moyle et al. 2017)

For adult steelhead populations originating in California (California Central Valley DPS, Central California Coast DPS, South Central California DPS), we do not expect these individuals to be exposed to the proposed action while in their staging areas, because California rivers are outside the action area. Adult steelhead of other populations could be exposed to the proposed seismic activities while in the marine environment, possibly while transiting to staging areas near their natal rivers.

Due to the timing of the action, we do not expect juvenile steelhead distinct population segments while entering the ocean. All juvenile steelhead could potentially be exposed to the proposed action while in the marine environment.

Salmonid Exposure: Water Depth

The seismic survey tracklines will be in water depths from 60 to 4,400 meters, and will overlap in areas where we expect Chinook, Coho, chum, sockeye, and steelhead to be exposed. In order to assess exposure for Pacific salmon in this consultation, we need to establish where the species will be in relation to the seismic survey. This means considering two spatial factors: where the Pacific salmon and steelhead occur in relation to shore (e.g., in what water depths, along what oceanographic feature), and examining where in the water column they occur.

Chinook salmon are commonly found in the California Current, in nearshore environments. Thermal conditions are likely an important factor in their habitat use. In late summer and autumn (late July to November), tagged Chinook occupied cool areas (9 to 12 degrees Celsius), (Hinke et al. 2005). It is thought that the cool, upwelled water in the coastal shelf serves as a migratory corridor and feeding ground for Chinook and Coho (Bellinger et al. 2015).

Adult Coho salmon are found on the continental shelf from southeast Alaska to Monterey Bay, California (Weitkamp and Neely 2002a; Beacham et al. 2016). Some adults migrate to the offshore waters of the North Pacific (Quinn et al. 2005). Juveniles are initially found in the nearshore environment before moving to the continental shelf area with the adults (Beacham et al. 2016).

In June, in the continental shelf and oceanic waters off the coast of Washington, the average depth at capture for Coho was 85.6 meters, and 55 meters for Chinook, with Coho ranging further offshore. In June, 80 percent of yearling Coho and Chinook were found in the nearshore zone (about 30 meters water depth) to water depths of 124 and 83 meters, respectively (Peterson et al. 2010). In another sturdy, juvenile Chinook salmon were most frequently captured in waters less than 37 meters deep (Fisher 1995) near the Columbia River off Oregon and Washington between May and September.

Immature and maturing chum salmon are distributed widely throughout the offshore waters of the Gulf of Alaska, outside the action area (Salo 1991a). After entering the ocean, juvenile chum migrate northward from the Columbia River and Hood Canal along the coast until reaching Alaska (Johnson et al. 1997b).

Juvenile sockeye salmon use a narrow band along the coast to rapidly move northward from their natal river, leaving it in mid-May to mid-June, and arriving in the Gulf of Alaska by mid-June to mid-July. Adult sockeye salmon distribute widely in the offshore waters of the Gulf of Alaska (Gustafson et al. 1997; Tucker et al. 2015).

Adult steelhead occur in the north Pacific in the oceanic waters off the continental shelf. When they reach maturity, they migrate east back over the continental shelf to their natal rivers (Quinn 2005). In contrast to other juvenile salmon that use a north-south coastal migration route, juvenile steelhead quickly migrate west after leaving their natal rivers to the oceanic waters past the continental shelf. These movements can take as little as one to three days, with an average of ten days (Daly et al. 2014).

As described earlier, the airgun array will be towed at a depth of 12 meters. In a study conducted in fall (September and October) and winter (January to February) in the eastern Bering Sea, salmon most often occupy the upper level of the water column, with some variation by species and life stage (Walker et al. 2007). Some immature Chinook, sockeye, and chum were captured at depths between 30 and 60 meters, in addition to being caught in waters above 30 meters deep. Chinook and chum have the deepest vertical distributions, with Chinook having an average depth of 42 meters (average daily maxima of 130 meters deep), and chum occupying an average depth of 16 meters (average daily maxima of 58 meters) (Walker et al. 2007). Coho were found at an average depth of 11 meters, with an average daily maxima of 46 meters, and sockeye found at an average depth of 3 meters (average daily maxima of 19 meters) (Walker et al. 2007).

Both juvenile and adult steelhead are regarded as being surface-oriented, occupying the upper 10 meters of the water column (Light et al. 1989). Adult sockeye salmon occupy the upper 30 meters of the water column, with most occupying in the upper 10 meters (Quinn et al. 1989; Ogura and Ishida 1995). Juvenile sockeye are mostly found in the upper 15 meters of the column (Beamish et al. 2007).

Because steelhead occupy off shelf waters, we expect juvenile and adult steelhead to be exposed further offshore during the proposed action (in contrast to other Pacific salmon that mostly occupy continental shelf waters). Juvenile steelhead could be exposed to seismic activities during their off shelf movements.

Salmonid Density

For each ESA-listed salmon ESU, eulachon ESU and steelhead DPS, we estimated a density of animals in the action area based on information regarding the species' distribution and abundance. For abundance data, we used the 2020 biological opinion analyzing the effects of sixteen ESA Section 10(a)(1)(A) Scientific Research Permits in Oregon, Washington, Idaho and California affecting Salmon, Steelhead, Eulachon, Green Sturgeon and Rockfish in the West Coast Region (NMFS 2020). This information is presented in Table 57 by life stage and origin (i.e., natural, hatchery intact adipose fin, and hatchery adipose clip). ESA take prohibitions do not apply to hatchery fish with clipped adipose fins from threatened ESUs/DPSs.

Table 53. Summary of estimated annual abundance of ESA-listed salmonids. Abundance estimates for each ESU and DPS are divided into natural, listed hatchery intact adipose, and listed hatchery adipose clip (NMFS 2020)[19].

Species	Life Stage	Natural	Listed Hatchery Intact Adipose	Listed Hatchery Adipose Clip
Sacramento River winter-run Chinook	Adult	210	-	2232
	Smolt	195,354	-	200,000
Central Valley spring-run Chinook	Adult	3,727	-	2,273
	Smolt	775,474	-	2,169,329
California Coastal Chinook	Adult	7,034	-	-

[19] Adult abundance numbers represent the total number of spawners. These do not factor in adults in the ocean environment.

Species	Life Stage	Natural	Listed Hatchery Intact Adipose	Listed Hatchery Adipose Clip
	Smolt	1,278,078	-	-
Snake River fall Chinook	Adult	10,337	13,551	15,508
	Smolt	692,819	2862418	2483713
Snake River spring/summer Chinook	Adult	12,798	421	2,387
	Smolt	1,007,526	775,305	4,453,663
Lower Columbia River Chinook	Adult	29,469	38,594[1]	-
	Smolt	11,745,027	962,458	31,353,395
Upper Willamette River Chinook	Adult	10,203	31,476[1]	-
	Smolt	1,211,863	157	4,709,045
Upper Columbia River spring Chinook	Adult	2,872	3364	6,226
	Smolt	468,820	368,642	621,759
Puget Sound Chinook	Adult	22,398	15,543[1]	-
	Smolt	3,035,288	7,271,130	36,297,500
Hood Canal summer run chum	Adult	25,146	1,452	-
	Smolt	3,889,955	150,000	-
Columbia River chum	Adult	10,644	426	-
	Smolt	662,6218	601,503	200,000
Central California Coast Coho	Adult	1,932	327	559
	Smolt	158,130	165,880	60,000
Southern Oregon/Northern California Coast Coho	Adult	9,065	10,934	-
	Parr	2,013,593	575,000	7,287,647
Oregon Coast Coho	Adult	94,320	0	-
	Parr	6,641,564	0	-
Lower Columbia River Coho	Adult	29,866	8,791	-
	Smolt	661,468	249,784	-
Ozette Lake sockeye	Adult	5,036[2]	0	0
	Smolt	1,037,787	259,250	45,750
Snake River sockeye	Adult	546	-	4,004
	Smolt	19,181	-	242,610
South-Central California steelhead	Adult	695	-	0
	Smolt	79,057	-	0
Central California Coast steelhead	Adult	2,187	-	3,866
	Smolt	248,771	-	648,891
California Central Valley steelhead	Adult	1,686	-	3,856
	Smolt	630,403	-	1,600,653

Species	Life Stage	Natural	Listed Hatchery Intact Adipose	Listed Hatchery Adipose Clip
Northern California steelhead	Adult	7,221	-	-
	Smolt	821,389	-	-
Upper Columbia River steelhead	Adult	1,931	1,163	5,309
	Smolt	199,380	138,601	687,567
Snake River Basin steelhead	Adult	10,547	16,137	79,510
	Smolt	798,341	705,490	3,300,152
Lower Columbia River steelhead	Adult	12,920	22297[1]	-
	Smolt	352,146	9138	1,197,156
Upper Willamette River steelhead	Adult	2,912	-	-
	Smolt	140,396	-	-
Middle Columbia River steelhead	Adult	5,052	112	448
	Smolt	407,697	110,469	444,973
Puget Sound steelhead	Adult	19,313[2]	-	-
	Smolt	2,196,901	112,500	110,000

[1] We do not have separate estimates for fin-clipped and intact adipose fin hatchery fish for the life stage of this DPS/ESU.
[2] Includes estimates for natural and hatchery fish (intact and clipped numbers)

NMFS (2020) only presented run-size estimates for fish returning to their natal rivers to spawn as a quantification of adults. The number of returning adults is an underestimate of the number of post-juvenile fish that will occur in the oceanic environment since most Chinook, chum, sockeye salmon and steelhead spend two to four years foraging and maturing in the ocean environment before returning to spawn. Coho salmon typically return to spawn at age three and thus spend approximately two years at sea, and eulachon typically spend three to five years at sea before returning to freshwater to spawn. Information is not available for all ESA-listed salmon and eulachon ESUs and steelhead DPSs to estimate the total oceanic abundance of these species (PFMC 2015). Therefore, we multiplied the number of returning adults for each ESU or DPS by the average number of years the species spends at sea before returning to spawn, in order to account for all age classes of fish that would be expected in the oceanic environment (i.e., three years for Chinook, chum, sockeye, and steelhead; two years for Coho; four years for eulachon). We recognize that since this methodology is based on the number of returning adults, it does not account for individuals that die before returning to spawn. However, this does not inhibit our ability to accurately assess jeopardy and determine whether or not to expect any population level effects from this action because we are assessing jeopardy and the potential for any population level effects by comparing effects from this action to the number of returning adults (which is generally how salmon, steelhead, and eulachon abundance and trends are tracked).

Once we estimated the ocean abundance of maturing/adult and juvenile fish from each ESU/DPS, we estimated a density based on the expected habitat area (distribution) in the marine environment for each species. This habitat area (distribution) data used for our density calculations is presented in Table 58 below, and a description of the data inputs used to calculate the offshore habitat of ESA-listed Chinook, chum, Coho, steelhead, and sockeye is discussed below.

We derived expected distribution data from NMFS (2015a) which calculated[20] the area (square kilometers) of offshore habitat for ESA-listed Chinook, chum, Coho, steelhead, and sockeye. The north-south oceanic distribution for Chinook was based on the results presented in Weitkamp (2010), which used coded-wire-tags to estimate the distribution of Chinook salmon from various recovery areas along the west coast of North America (See Figure 45 and Figure 46). Chinook distribution data from Shelton et al. (2019) was assessed, however it was determined that Weitkamp (2010) provided more comprehensive distribution data for all run types (spring, summer, fall, and winter) whereas Shelton et al. (2019) only provided data for fall run Chinook. For Coho, the north-south oceanic distribution was based on Weitkamp and Neely (2002b) which used a similar methodology.

Since Chinook and Coho primarily reside on the continental shelf, NMFS (2015a) used the shelf break as the westward boundary of these species' distribution (the shelf break was defined as the 200 meter depth contour; (Landry and Hickey 1989)). Similar studies were not available for chum, sockeye, and steelhead. Chum geographic distribution was based on the ocean migration of the species from British Columbia, Washington, and Oregon, as determined from tagging data and presented in Neave et al. (1976). The migration pattern described in Neave et al. (1976) did not include information on individuals found immediately offshore of their river of origin in Oregon and Washington. Chum migrate north and west once they leave their river of origin (Quinn 2005; Byron and Burke 2014) and are generally found on the continental shelf, inshore of 37 kilometers from the coast (Pearcy and Fisher 1990). Therefore, NMFS (2015a) added the area of the continental shelf from each ESU's river of origin north to the mouth of Puget Sound (the area southernmost point where Neave et al. (1976) presented tagging data). NMFS (2015a) used the same geographic distribution for sockeye as it did for chum because in general, it is thought that sockeye follow a similar migration pattern once they enter the ocean, moving north and west along the coast, and having moved offshore by the end of their first ocean year (Quinn 2005; Byron and Burke 2014). For steelhead, NMFS (2015a) relied on the geographic ocean distribution of the species during summer described in Light et al. (1989).

[20] Area of offshore habitat was calculated using ArcMap version 10.2.1 (ESRI, Redlands, CA)

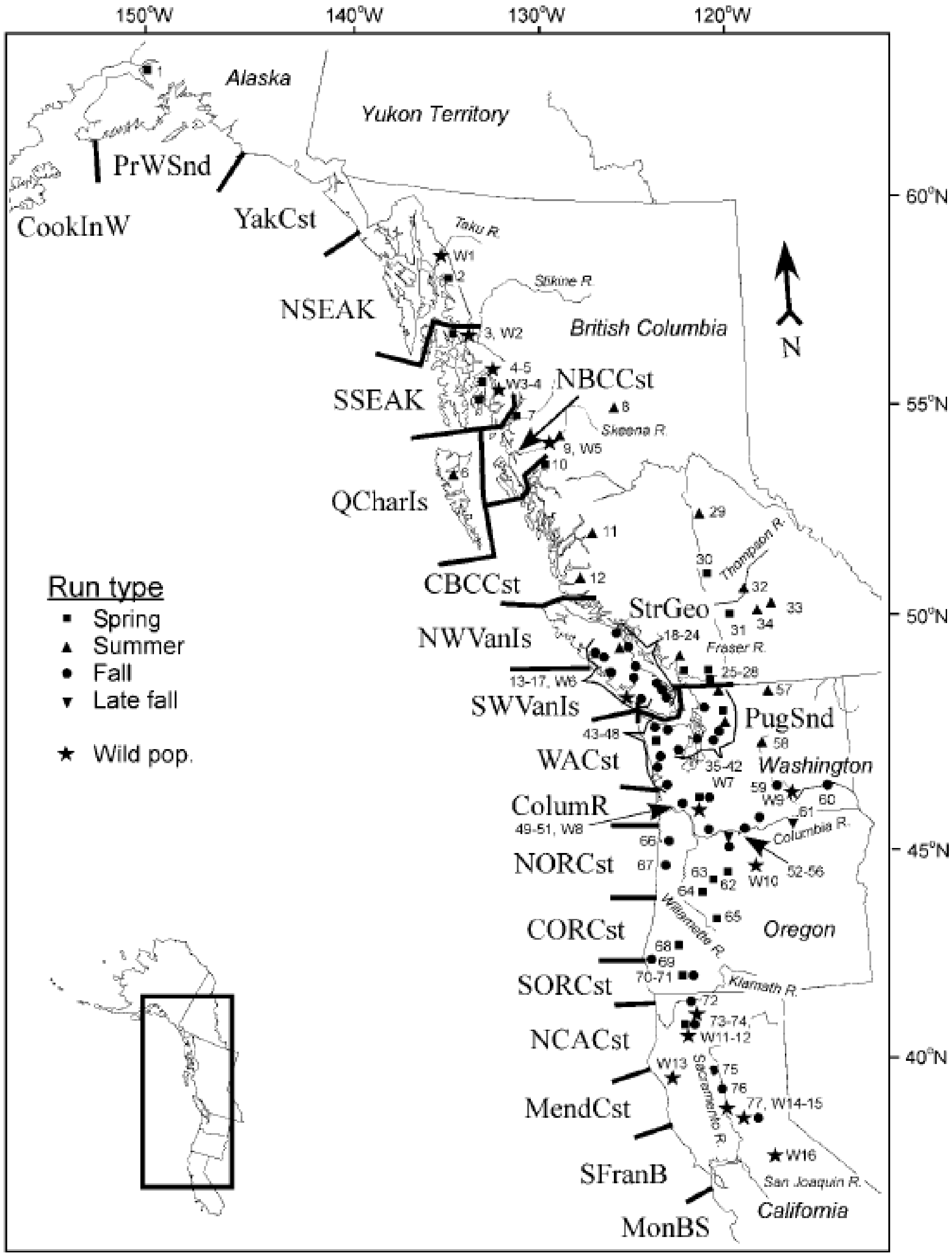

Figure 44. Locations of the 21 marine recovery areas (indicated by dark lines) used to estimate distributions (Weitkamp 2010).

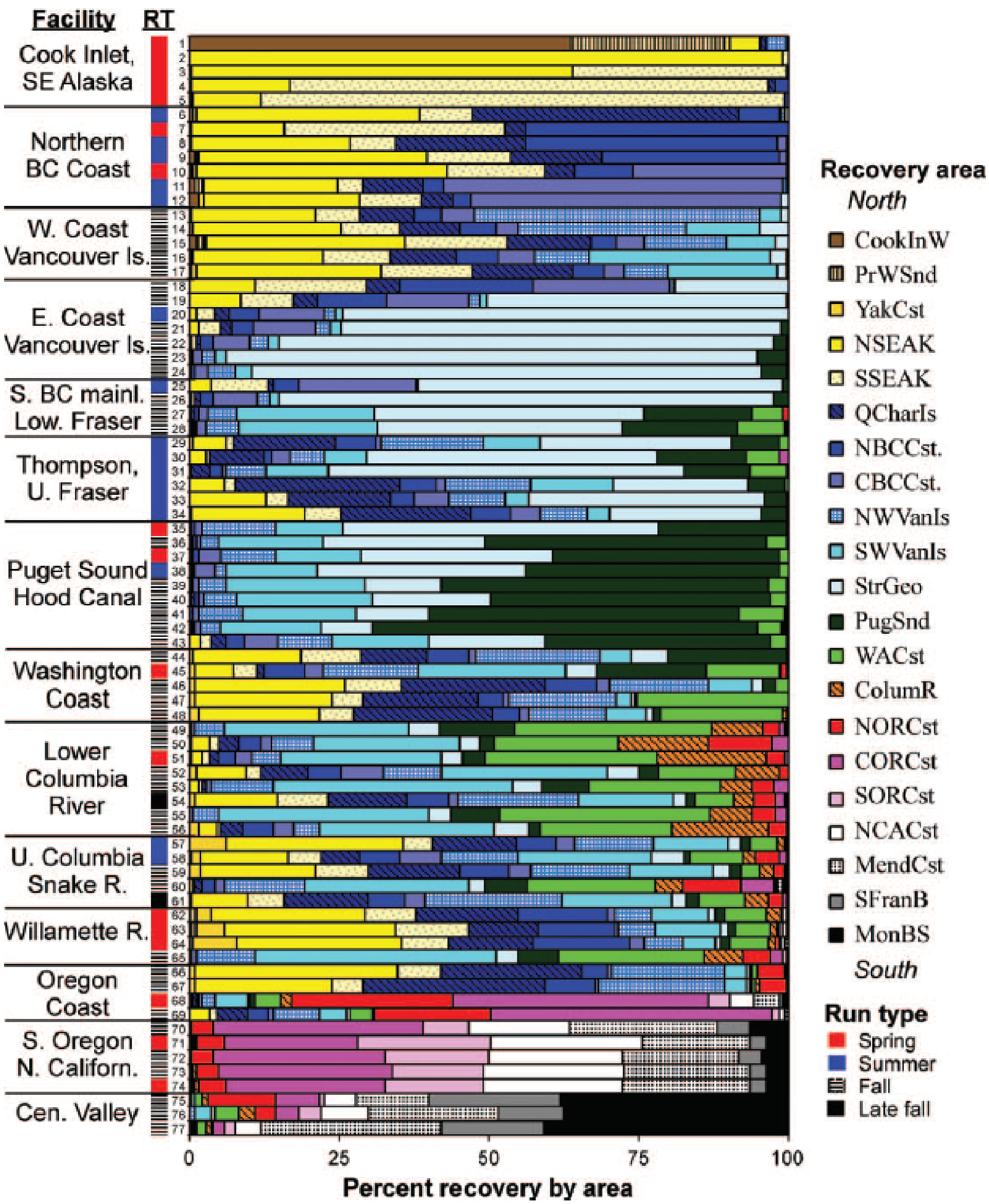

Figure 45. Recovery patterns for coded-wire-tagged Chinook salmon. Each horizontal bar represents the percentages of recoveries in the 21 marine recovery areas for a single hatchery run type group (Weitkamp 2010).

Table 54. Habitat area (distribution) used for each salmonid ESU/DPS (km^2) in the offshore marine environment.[21]

DPS/ESU	Marine Habitat Area (km^2)
Sacramento River winter-run Chinook	123,717
Central Valley spring-run Chinook	123,717
California Coastal Chinook	64,316
Snake River fall Chinook	657,628
Snake River spring/summer Chinook	657,628
Lower Columbia River Chinook	562,179
Upper Willamette River Chinook	634,343
Upper Columbia River spring Chinook	657,628
Puget Sound Chinook	241,626
Chum (all ESUs)	4,414,073
Central California Coast Coho	49,908
Southern Oregon/Northern California Coast Coho	181,607
Oregon Coast Coho	131,699
Lower Columbia River Coho	106,339
Sockeye (all ESUs)	4,414,073
Steelhead (all DPSs)	13,339,020

Offshore densities used for ESA-listed salmonids are presented in Table 59. These densities were developed using the abundance data in Table 57 and the marine habitat distribution area information in Table 58.

Table 55. Offshore density estimates for ESA-listed salmonids in the action area.

Species	Life stage	ESU/DPS	Density (# fish/km^2)
Chinook	Adult	Sac River winter run	0.059216
	Juvenile		3.195632
	Adult	Central valley spring run	0.145493
	Juvenile		23.80274
	Adult	California coastal	0.328099
	Juvenile		19.87185
	Adult	Snake River fall	0.179719
	Juvenile		9.182927
	Adult	Snake River spring/summer	0.071192

[21] It is important to note that these distributions are representative of the majority of area a specific ESU/DPS may be found, not inclusive of everywhere where an ESU/DPS has been caught.

Species	Life stage	ESU/DPS	Density (# fish/km^2)
	Juvenile		9.483316
	Adult	Lower Columbia River	0.36321
	Juvenile		78.37518
	Adult	Upper Willamette River	0.197113
	Juvenile		9.334169
	Adult	Upper Columbia River spring	0.05685
	Juvenile		2.218916
	Adult	Puget Sound	0.471071
	Juvenile		192.8763
Coho	Adult	Central Calif coast	0.090527
	Juvenile		6.492146
	Adult	S. Oregon/N. Calif coast	0.220245
	Juvenile		15.3551
	Adult	Oregon coast	1.440846
	Juvenile		50.88546
	Adult	Lower Columbia River	0.727052
	Juvenile		77.10152
Chum	Adult	Hood Canal summer run	0.017961
	Juvenile		0.90934
	Adult	Columbia River	0.007475
	Juvenile		1.626864
Sockeye	Adult	Ozette Lake	0.001134
	Juvenile		0.302244
	Adult	Snake River	0.003072
	Juvenile		0.058926
Steelhead	Adult	South-Central California	0.000156
	Juvenile		0.005927
	Adult	Central Calif	0.000492
	Juvenile		0.018650
	Adult	California Central Valley	0.000379
	Juvenile		0.047260
	Adult	Northern Calif	0.001624
	Juvenile		0.061578
	Adult	Upper Columbia River	0.000434
	Juvenile		0.014947
	Adult	Snake River basin	0.002372
	Juvenile		0.059850
	Adult	Lower Columbia River	0.002906
	Juvenile		0.026400
	Adult	Upper Willamette River	0.000655
	Juvenile		0.010525
	Adult	Middle Columbia River	0.001136
	Juvenile		0.030564
	Adult	Puget Sound	0.004344
	Juvenile		0.164697

Salmonid Exposure Numbers

To determine exposure, we used the acoustic thresholds and resulting isopleths and then used GIS to establish a buffer around the tracklines to calculate the amount of area ensonified throughout the action area. As discussed earlier, the continental shelf (waters less than 200 meters deep) represents important habitat for ESA-listed fishes. In order to estimate exposure for fish, we needed to focus on the areas of habitat that overlapped with the action area where we think it is most likely ESA-listed salmonids will occur. Although steelhead can exhibit a more offshore distribution, the 200 meter depth line was used as a conservative measure to illustrate where they are mainly located. About 2,184 kilometers will take place in waters less than 200 meters deep in the waters of the continental shelf (33.4 percent of the tracklines for the total survey). The amount of ensonified area in waters less than 200 meters deep to the 187 dB level is 14,218 km^2. The amount of ensonified areas in waters less than 200 meters deep to the 206 dB level is 911 km^2. These levels correspond to the thresholds for the onset of injury and TTS in fish with swim bladders; see Section 10.2.2.3 for more discussion. We used these ensonified areas and multiplied them by the density of each ESA-listed salmonid population to calculate the number of Pacific salmonids exposed to the proposed action.

Results from these calculations of the estimated number of ESA-listed salmonids that would experience TTS or be injured are presented in Table 60, Table 61, and Table 62.

Oceanographic conditions like coastal upwellings are possibly related to the distribution of salmonids. Peterson et al. (2010) observed greater abundance of juvenile salmonids in Washington shelf waters than Oregon, and proposed that there are features in Washington waters that may make that habitat more conducive for juveniles. These features included strong stratification in shelf waters, more productive shelf waters due to nutrients being resupplied from the Strait of Juan de Fuca, less upwelling in Washington than in Oregon, and reduced salinity in Washington shelf waters because of input from the Strait of Juan de Fuca, the Columbia River plume, and upwelled, subarctic waters. Thus, we have some reason to believe that juvenile salmonids are not evenly distributed throughout the action area, and may be more prevalent in Washington shelf waters than in Oregon, which would lead us to expect that there could be more exposure of juvenile salmonids in Washington waters. However, since we are not able to quantify to what degree juvenile salmonids are more prevalent throughout the action area, we will conservatively assume that they are evenly distributed.

Eulachon Exposure

ESA-listed Southern DPS of eulachon occur in the marine environment and may be exposed to the proposed action. Southern DPS of eulachon are found on the continental shelf off the U.S. West Coast and are most often at depth between 50 to 200 meters (164 to 656 feet) (Gustafson 2016b). Although eulachon have been documented to occur in deeper water depths (maximum of 625 meters), these instances are rare and have only been observed from Alaskan trawl data which may greatly overestimate eulachon's true maximum depth as fish may become entrained into the nets, either on deployment or recovery (Hay and McCarter 2000). Approximately 2,184 kilometers of tracklines for the proposed action will take place in waters less than 200 meters deep, overlapping with the range of eulachon.

Spawning adult eulachon enter the Lower Columbia River estuary from late December to March, while larvae drift downstream into the ocean from February to March (Gustafson 2016a). In research trawl surveys, most juvenile eulachon are taken at around 100 meters depth in British Columbia and between 137 and 147 meters off the U.S. West Coast (defined as Washington, Oregon and California) (Gustafson et al. 2012). This species typically spends three to five years in saltwater before returning to freshwater to spawn.

To determine the average density of southern DPS eulachon in the offshore environment we used a similar methodology as described for estimating salmonid densities above. NMFS (2015a) determined that the southern DPS of eulachon has a marine distribution area of 1,183,304 km^2. The latest estimate of the population abundance of the southern DPS of eulachon was 18,796,090 spawners estimated in the Columbia River and Fraser River from 2014 to 2018. Because we do not have estimates of eulachon abundance in marine waters, the number of spawners in the Columbia River and Fraser River was used as a proxy for abundance in the oceanic environment. We multiplied the number of returning adults by the average number of years the species spends at sea before returning to spawn, in order to account for all age classes of fish that would be expected in the oceanic environment (i.e., four years for eulachon). This method produced a total Southern DPS eulachon density estimate of 63.54 km^2, which resulted in 903,412 individuals exposed to sound from the proposed action.

Green Sturgeon Exposure

The proposed seismic survey activities will take place in waters that may be occupied by Southern DPS of green sturgeon. Sub-adult and adult green sturgeon spend most of their lives in the marine environment, at water depths between 20 to 70 meters (66 to 230 feet) (Erickson and Hightower 2007; Huff et al. 2011), from southern California to Alaska (NMFS 2015f). There will be about 196 kilometers of tracklines that will take place in water depths less than 100 meters (out of a total of about 6,540 kilometers overall for the entire survey). Even when the survey tracklines are not taking place directly in water depths where southern DPS green sturgeon occur, because of the size of the ensonified area, sound created by the airgun array could extend into places where they are, exposing them to the seismic activities.

The limited feeding data available for adult green sturgeon show that they consume benthic invertebrates including shrimp, clams, chironomids, copepods, mollusks, amphipods, and small fish (Houston 1988; Moyle et al. 1992b; Wilson and McKinley 2004; Dumbauld et al. 2008). Information regarding their preference for areas of high seafloor complexity and prey selection in coastal waters (benthic prey) indicate green sturgeon reside and migrate along the seafloor while in coastal waters. The airgun array is directed downward, so it is likely that the proposed action will expose green sturgeon while they are feeding at the ocean floor.

The timing of the proposed action is significant in terms of likelihood of green sturgeon exposure. In July and August, tagged green sturgeon moved into shallower water (20 meters deep or less) (Huff et al. 2011). Satellite tagging data from 2019 indicate that up until mid-July, tagged green sturgeon are using the coastal waters of Washington, moving into the shallow coastal waters near the Columbia River by late July (J. Smith, pers comm.).

The seismic survey will begin sometime around June 1st, with the vessel leaving Newport, Oregon. Due to operational considerations that will take place on the spot, the NSF does not know fine-scale details about how the survey will occur—that is, if the survey will start from the north and go south, start with the inshore tracklines, or vice versa. Thus, it is still possible that green sturgeon could be exposed before they move into shallower water later in July and into August. However, due to the timing of the survey, the overall low amount of the survey that will take place in waters less than 100 meters deep, and that we expect green sturgeon to spend a portion of the time of the proposed action in shallow waters outside of the action area, we expect an overall low amount of green sturgeon exposure.

We were unable to determine the density of Southern DPS green sturgeon in the action area. There is an array of NMFS acoustic receivers off the coast of Washington, but none within the action area. As a result, we were not able to use data from those receivers to calculate a density.

We are relying on the extent of the ensonified area as a surrogate to estimate green sturgeon exposure. If a green sturgeon is within this area during seismic operations, it would be exposed to the stressor (i.e., the sound field produced by the airguns).

10.2.2 Response Analysis

A pulse of sound from the airgun array displaces water around the airgun array and creates a wave of pressure, resulting in physical effects on the marine environment that can then affect marine organisms, such as ESA-listed marine mammals, sea turtles, and fishes considered in this opinion. Possible responses considered in this analysis consist of:

- Hearing threshold shifts;
- Auditory interference (masking);
- Behavioral responses; and
- Non-auditory physical or physiological effects.

The *Response Analysis* also considers information on the potential for stranding and the potential effects on prey of ESA-listed marine mammals and sea turtles in the action area.

As discussed in *The Assessment Framework* (Section 2) of this opinion, response analyses determine how ESA-listed resources are likely to respond after exposure to an action's effects on the environment or directly on ESA-listed species themselves. For the purposes of consultation, our assessments try to detect potential lethal, sub-lethal (or physiological), or behavioral responses that might result in reduced fitness of ESA-listed individuals. Ideally, response analyses will consider and weigh evidence of adverse consequences as well as evidence suggesting the absence of such consequences.

The National Science Foundation, L-DEO, and NMFS Permits and Conservation Division estimated the number of ESA-listed marine mammals that may be exposed to received levels greater than or equal to 160 dB re: 1 μPa (rms) for the sound sources associated with the proposed action. The exposure estimates stem from the best available information on marine mammal densities (Table 45) and a predicted radius (rms; Table 2) along seismic survey tracklines. ESA-listed marine mammals exposed to these sound sources could be harmed, exhibit changes in behavior, suffer stress, or even strand.

To determine exposures, the National Science Foundation, L-DEO, and NMFS Permits and Conservation Division calculated ESA harm and harassment by using the radial distances from the airgun array to the predicted isopleths corresponding to MMPA Level A and Level B harassment. The area estimated to be ensonified in a single day (187 kilometers [101 nautical miles] for the two-dimensional seismic survey is then calculated, based on the areas predicted to be ensonified around the airgun array and representative trackline distances traveled per day. The ensonified areas were then multiplied by the number of survey days. The product is then multiplied by 1.25 to account for the additional 25 percent contingency. This results in an estimate of the total area expected to be ensonified. The total area ensonified at 160 dB re: 1 μPa (rms) is 79,581.9 square kilometers (23,202.4 square nautical miles), which was calculated in the geographic information system mapping program by multiplying the 160 dB harassment buffer zone widths for the different airgun array configurations by the trackline distance. The number of marine mammals that can be exposed to the sounds from the airgun array on one or more occasions is estimated for the calculated marine area along with the expected density of animals in the area. Summing exposures along all of the tracklines yields the total exposures for each species for the proposed action for the 36-airgun array configuration for the seismic survey activities. The method also yields exposures for each seismic survey trackline individually, allowing examination of those exemplary tracklines that will yield the largest or smallest exposures. The approach assumes that no marine mammals will move away or toward the trackline in response to increasing sound levels before the levels reach the specific thresholds as the R/V *Marcus G. Langseth* approaches. This calculation assumes 100 percent turnover of individuals within the ensonified area on a daily basis, that is, each individual exposed to the seismic survey activities is a unique individual that may exhibit a response.

Based on information provided by the National Science Foundation and L-DEO, we have determined that marine mammals are likely to be exposed to sound levels at or above the threshold at which TTS and behavioral responses will occur. From modeling by the L-DEO, the National Science Foundation and L-DEO provided sound source levels of the airgun array (Table 4) and estimated distances for the 160 dB re: 1 μPa (rms) sound levels, as well as MMPA Level A harassment thresholds generated by the airgun array configurations (single airgun and the full 36 airgun array) and water depth. To briefly summarize, for the 36-airgun array, the predicted distances to the 160 dB re: 1 μPa (rms) sound level threshold for MMPA Level B harassment in shallow, intermediate and deep water are 12,650 meters, 9,648 meters, and 6,733 meters, respectively. The modeled radial distances for permanent threshold shift thresholds (MMPA Level A harassment) for various marine mammal hearing groups were presented in Table 4.

In developing the National Science Foundation's draft environmental analysis and L-DEO's incidental harassment authorization application, they used estimates of marine mammal densities in the action area synthesized by CetSound (https://cetsound.noaa.gov/cda-index), and its underlying data found in (Becker et al. 2016), as well as that developed by (Navy 2019) for the Northwest Testing and Training Area, which overlaps with the action area.

The L-DEO used the GIS files that are the outputs for the habitat-based density models created by CetSound. The density estimates were available in the form of a GIS grid with each cell in the grid measuring about 7 kilometers east to west by 10 kilometers north to south. The L-DEO then used this grid to intersect it with a GIS layer of the areas expected to be ensonified to 160 dB SPL threshold within the three water depth categories (< 100 meters, 100 to 1000 meters, and >1000 meters). The densities from all grid cells overlapping the ensonified areas within each water depth category were averaged to calculate a zone-specific density for each species to determine number of animals exposed (Table 45).

An estimate of the number of marine mammals that will be exposed to sounds from the airgun array is also included in the National Science Foundation's draft environmental analysis. The National Science Foundation, L-DEO, and NMFS Permits and Conservation Division did not provide any estimates from sound sources other than the airgun array, although other equipment producing sound will be used during airgun array operations (e.g., the multi-beam echosounder, sub-bottom profiler, acoustic Doppler current profiler, and acoustic release transponder).

In their *Federal Register* notice of the proposed incidental harassment authorization, the NMFS Permits and Conservation Division stated that they did not expect the sound emanating from the other equipment to exceed the levels produced by the airgun array. Therefore, the NMFS Permits and Conservation Division did not expect additional responses from sound sources other than the airgun array. We agree with this assessment and similarly focus our analysis on responses to sound from the airgun array. The multi-beam echosounder, sub-bottom profiler, acoustic Doppler current profiler, and acoustic release transponder are also expected to affect a smaller ensonified area within the larger sound field produced by the airgun array and are not expected to be of sufficient duration that will lead to the onset of TTS or PTS for an animal.

During the development of the incidental harassment authorization, the NMFS Permits and Conservation Division conducted an independent analysis that was informed by comments received during the public comment period for the proposed incidental harassment authorization and a draft environmental analysis prepared under the National Environmental Policy Act and Executive Order 12114. The analysis also included estimates of the number of ESA-listed marine mammals likely to be exposed to received levels at MMPA Level A harassment thresholds in the absence of monitoring and mitigation measures (conservation measures) that will be required as part of the IHA.

In this section, we describe the National Science Foundation, L-DEO, and NMFS Permits and Conservation Division's analytical methods to estimate the number of ESA-listed marine mammal species that might be exposed to the sound field and experience an adverse response. We also rely on acoustic thresholds to determine sound levels at which marine mammals are expected to exhibit a response, utilize these thresholds to calculate ensonified areas, and, finally, either multiply these areas by data on marine mammal density or use the sound field in the water column as a surrogate to estimate the number of marine mammals exposed to sounds levels generated by the airgun array that are likely to result in adverse effects to the animals.

Acoustic Thresholds

Acoustic thresholds are used in the development of radii for exclusion zones around a sound source and the necessary mitigation requirements necessary to limit marine mammal exposure to harmful levels of sound (NOAA 2018) under an MMPA authorization. For Level B harassment under the MMPA and responses under the ESA, NMFS has historically relied on an acoustic threshold for 160 dB re: 1 μPa (rms). This value is based on observations of behavioral responses of mysticetes, but is used for all marine mammal species. For the proposed action, the NMFS Permits and Conservation Division continued to rely on this historic NMFS acoustic threshold to estimate the number of takes by MMPA Level B harassment, and accordingly, adverse effects to ESA-listed marine mammals that are proposed in the incidental harassment authorization.

For physiological responses to active acoustic sources, such as TTS and PTS, the NMFS Permits and Conservation Division relied on NMFS' technical guidance for auditory injury of marine mammals (NOAA 2018). Unlike NMFS' 160 dB re: 1 μPa (rms) MMPA Level B harassment threshold (which does not include TTS or PTS), these TTS and PTS auditory thresholds differ by species hearing group (Table 57). Furthermore, these acoustic thresholds are a dual metric for impulsive sounds, with one threshold based on peak sound pressure level (0 to peak SPL) that does not include the duration of exposure. The other metric, the cumulative sound exposure criteria, incorporate auditory weighting functions based upon a species group's hearing sensitivity, and thus susceptibility to TTS and PTS over the exposed frequency range and duration of exposure. The metric that results in the largest distance from the sound source (i.e., produces the largest field of exposure) is used in estimating total range to potential exposure and effect, because it is the more precautionary criteria. In recognition of the fact that the requirement to calculate ensonified areas can be more technically challenging to predict due to the duration component and the use of weighting functions in the new SEL_{cum} thresholds, NMFS developed an optional user spreadsheet that includes tools to help predict a simple isopleth that can be used in conjunction with marine mammal density or occurrence to facilitate the estimation of the numbers that may be adversely affected by sound.

In using these acoustic thresholds to estimate the number of individuals that may experience auditory injury, the NMFS Permits and Conservation Division classify any exposure equal to or above the acoustic threshold for the onset of PTS (see Table 57) as auditory injury, and thus MMPA Level A harassment, and adverse effects under the ESA. Any exposure below the threshold for the onset of PTS, but equal to or above the 160 dB re: 1 μPa (rms) acoustic threshold is classified as MMPA Level B harassment. The NMFS Permits and Conservation Division does not distinguish between those individuals that are expected to experience TTS and those that will only exhibit a behavioral response.

Table 56. Functional hearing groups, generalized hearing ranges, and acoustic thresholds identifying the onset of permanent threshold shift and temporary threshold shift for marine mammals exposed to impulsive sounds (NOAA 2018).

Hearing Group	Generalized Hearing Range*	Permanent Threshold Shift Onset	Temporary Threshold Shift Onset
Low-Frequency Cetaceans (Baleen Whales) (LE,LF,24 hour)	7 Hertz to 35 kilohertz	$L_{pk,flat}$: 219 dB $L_{E,LF,24h}$: 183 dB	213 dB peak SPL 168 dB SEL
Mid-Frequency Cetaceans (Dolphins, Toothed Whales, Beaked Whales, Bottlenose Whales) (LE,MF,24 Hour)	150 Hertz to 160 kilohertz	$L_{pk,flat}$: 230 dB $L_{E,MF,24h}$: 185 dB	224 dB peak SPL 170 dB SEL
Otariid Pinnipeds (Guadalupe Fur Seals) (LE,MF,24 Hour) – Underwater	60 Hertz to 39 kilohertz	$L_{pk,flat}$: 232 dB $L_{E,MF,24h}$: 203 dB	212 dB peak SPL 170 dB SEL

LE, X, 24 Hour=Frequency Sound Exposure Level (SEL) Cumulated over 24 Hour
LF=Low Frequency
MF=Mid-Frequency
*Represents the generalized hearing range for the entire group as a composite (i.e., all species within the group), where individual species' hearing ranges are typically not as broad. Generalized hearing range chosen based on approximately 65 dB threshold from normalized composite audiogram, with the exception for lower limits for low frequency cetaceans (Southall et al. 2007b) (approximation).
Note: Dual metric acoustic thresholds for impulsive sounds (peak and/or SEL_{cum}): Use whichever results in the largest (most conservative for the ESA-listed species) isopleth for calculating PTS onset. If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.
Note: Peak sound pressure (Lpk) has a reference value of 1 μPa, and cumulative sound exposure level (LE) has a reference value of 1 μPa^2s. In this table, thresholds are abbreviated to reflect American National Standards Institute standards (ANSI 2013). However, peak sound pressure is defined by ANSI as incorporating frequency weighting, which is not the intent for this technical guidance. Hence, the subscript "flat" is being included to indicate peak sound pressure should be flat weighted or unweighted within the generalized hearing range. The subscript associated with cumulative sound exposure level thresholds indicates the designated marine mammal auditory weighting function and that the recommended accumulation period is 24 hours. The cumulative sound exposure level thresholds could be exceeded in a multitude of ways (i.e., varying exposure levels and durations, duty cycle). When possible, it is valuable for action proponents to indicate the conditions under which these acoustic thresholds will be exceeded.

Using the above acoustic thresholds, the NMFS Permits and Conservation Division evaluated the exposure and estimates of ESA-listed marine mammals expected to measurably respond to the adverse effects of the sounds from the airgun array.

10.2.2.1 Potential Response of Marine Mammals to Acoustic Sources

Exposure of marine mammals to very strong impulsive sound sources from airgun arrays can result in auditory damage, such as changes to sensory hairs in the inner ear, which may temporarily or permanently impair hearing by decreasing the range of sound an animal can detect within its normal hearing ranges. Hearing threshold shifts depend upon the duration, frequency, sound pressure, and rise time of the sound. A TTS results in a temporary change to hearing sensitivity (Finneran 2013), and the impairment can last minutes to days, but full recovery of hearing sensitivity is expected. However, a study looking at the effects of sound on mice hearing, has shown that, although full hearing can be regained from TTS (i.e., the sensory cells actually receiving sound are normal), damage can still occur to the cochlear nerve leading to delayed but permanent hearing damage (Kujawa and Liberman 2009). At higher received levels, particularly in frequency ranges where animals are more sensitive, PTS can occur, meaning lost auditory sensitivity is unrecoverable. Either of these conditions can result from exposure to a single pulse or from the accumulated effects of multiple pulses, in which case each pulse need not be as loud as a single pulse to have the same accumulated effect. A TTS and PTS are generally specific to the frequencies over which exposure occurs but can extend to a half-octave above or below the center frequency of the source in tonal exposures (less evident in broadband noise such as the sound sources associated with the proposed action; (Schlundt 2000; Kastak 2005; Ketten 2012)).

Few data are available to precisely define each ESA-listed species hearing range, let alone its sensitivity and levels necessary to induce TTS or PTS. Baleen whales (e.g., blue, fin, humpback, and sei whales) have an estimated functional hearing frequency range of 7 Hertz to 35 kilohertz and sperm whales have an estimated functional hearing frequency range of 150 Hertz to 160 kilohertz (see Table 44) (Southall 2007). For pinnipeds in water, data are limited to measurements of TTS in harbor seals (*Phoca vitulina*), an elephant seal (*Mirounga angustirostris*), and California sea lions (*Zalophus californianus*) (Kastak et al. 1999; Kastelein et al. 2012). Otariid sea lions and fur seals, like Guadalupe fur seals, have an estimated functional hearing range of 60 Hertz to 39 kilohertz.

Based upon captive studies of odontocetes, our understanding of terrestrial mammal hearing, and extensive modeling, the best available information supports the position that sound levels at a given frequency will need to be approximately 186 dB SEL or approximately 196 to 201 dB re: 1 μPa (rms) in order to produce a low-level TTS from a single pulse (Southall et al. 2007d). PTS is expected at levels approximately 6 dB greater than TTS levels on a peak-pressure basis, or 15 dB greater on an SEL basis than TTS (Southall et al. 2007d). In terms of exposure to the R/V *Marcus G. Langseth*'s airgun array, an individual will need to be within a few meters of the largest airgun to experience a single pulse greater than 230 dB re: 1 μPa (peak) (Caldwell and Dragoset 2000). If an individual experienced exposure to several airgun pulses of approximately 219 dB for low-frequency cetaceans, 230 dB for mid-frequency cetaceans, or 202 dB for high-frequency cetaceans, PTS could occur. Marine mammals (cetaceans and pinnipeds) will have to be within certain modeled radial distances specified in Table 2 and Table 4 from the R/V *Marcus*

G. Langseth's single airgun and 36 airgun array to be within the MMPA Level A harassment to be within the threshold isopleth and risk a PTS and within the MMPA Level B harassment to be within the threshold isopleth and risk behavioral responses.

Research and observations show that pinnipeds in the water are tolerant of anthropogenic noise and activity. If Guadalupe fur seals are exposed to active acoustic sources, they may react in a number of ways depending on their experience with the sound source and what activity they are engaged in at the time of the acoustic exposure. Guadalupe fur seals may not react at all until the sound source is approaching within a few hundred meters and then may alert, approach, ignore the stimulus, change their behaviors, or avoid the immediate area by swimming away or diving (Finneran et al. 2003a; Kvadsheim et al. 2010; Götz and Janik 2011). Significant behavioral reactions would not be expected in most cases, and long-term consequences for individuals are unlikely.

Ranges to some behavioral impacts can take place at distances exceeding 100 kilometers (54 nautical miles), although significant behavioral effects are much more likely at higher received levels within a few kilometers of the sound source. Behavioral reactions will be short-term, likely lasting the duration of the exposure, and long-term consequences for individuals.

Overall, we do not expect TTS to occur to any ESA-listed marine mammals because of exposure to the airgun array. We expect that most individuals will move away from the airgun array as it approaches; however, a few individuals may be exposed to sound levels that may result in TTS or PTS, but we expect the probability to be low. As the seismic survey proceeds along each transect trackline and approaches ESA-listed individuals, the sound intensity increases and individuals will experience conditions (stress, loss of prey, discomfort, etc.) that prompt them to move away from the research vessel and sound source and thus avoid exposures that will induce TTS or PTS. Ramp-ups will also reduce the probability of TTS-inducing exposure at the start of seismic survey activities for the same reasons, as acoustic intensity increases, animals will move away and therefore unlikely to accumulate more injurious levels. Furthermore, mitigation measures will be in place to initiate a shut-down if individuals enter or are about to enter the 500 meter (1,640.4 feet) exclusion zone during full airgun array operations, which is beyond the distances believed to have the potential for PTS in any of the ESA-listed marine mammals as described above. Each individual may be exposed to 160 dB re: 1 μPa (rms) levels. We do not expect this to produce a cumulative TTS or other physical injury for several reasons. Specifically, we expect that individuals will recover from TTS between each of these exposures, we expect monitoring to produce some degree of mitigation such that exposures will be reduced, and (as stated above), we expect individuals to generally move away at least a short distance as received sound levels increase, reducing the likelihood of exposure that is biologically meaningful. In summary, we do not expect animals to be present for a sufficient duration to accumulate sound pressure levels that will lead to the onset of TTS or PTS.

Marine Mammals and Auditory Interference (Masking)

Interference, or masking, occurs when a sound is a similar frequency and similar to or louder than the sound an animal is trying to hear (Clark et al. 2009; Erbe et al. 2016). Masking can interfere with an individual's ability to gather acoustic information about its environment, such as predators, prey, conspecifics, and other environmental cues (Richardson 1995). This can result in loss of environmental cues of predatory risk, mating opportunity, or foraging options (Francis and Barber 2013). Low frequency sounds are broad and tend to have relatively constant bandwidth, whereas higher frequency bandwidths are narrower (NMFS 2006c).

There is frequency overlap between airgun array sounds and vocalizations of ESA-listed marine mammals, particularly baleen whales and to some extent sperm whales. The proposed seismic survey could mask whale calls at some of the lower frequencies for these species. This could affect communication between individuals, affect their ability to receive information from their environment, or affect sperm whale echolocation (Evans 1998; NMFS 2006c). Most of the energy of sperm whale clicks is concentrated at 2 to 4 kilohertz and 10 to 16 kilohertz and, though the findings by Madsen et al. (2006) suggest frequencies of pulses from airgun arrays can overlap this range, the strongest spectrum levels of airguns are below 200 Hertz (2 to 188 Hertz for the R/V *Marcus G. Langseth*'s airgun array). Any masking that might occur will likely be temporary because acoustic sources from the seismic surveys are not continuous and the research vessel will continue to transit through the area during the survey rather than remaining in a particular location. In addition, the proposed seismic survey activities on the R/V *Marcus G. Langseth* are planned to occur over the course of approximately 37 days, including approximately three days of equipment deployment and retrieval and approximately two days of transit, for seismic survey in the Northeast Pacific Ocean in June and July 2021.

Given the disparity between sperm whale echolocation and communication-related sounds with the dominant frequencies for seismic surveys, masking is not likely to be significant for sperm whales (NMFS 2006c). Overlap of the dominant low frequencies of airgun pulses with low-frequency baleen whale calls may pose a somewhat greater risk of masking. The R/V *Marcus G. Langseth*'s airguns will emit a 0.1-second pulse when fired approximately every 16 to 17 seconds, with sperm whale calls lasting 0.5 to 1 second. Therefore, pulses will not "cover up" the vocalizations of ESA-listed sperm whales to a significant extent (Madsen et al. 2002b). We address the response of ESA-listed marine mammals stopping vocalizations because of airgun sound in the *Marine Mammals and Behavioral Responses* section below.

Although sound pulses from airguns begin as short, discrete sounds, they interact with the marine environment and lengthen through processes such as reverberation. This means that in some cases such as in shallow water environments, airgun sound can become part of the acoustic background. Few studies of how impulsive sound in the marine environment deforms from short bursts to lengthened waveforms exist, but can apparently add significantly to acoustic background (Guerra et al. 2011), potentially interfering with the ability of animals to hear otherwise detectible sounds in their environment.

The sound localization abilities of marine mammals suggest that, if signal and sound come from different directions, masking will not be as severe as the usual types of masking studies might suggest (Richardson 1995). The dominant background noise may be highly directional if it comes from a particular anthropogenic source such as a ship or industrial site. Directional hearing may significantly reduce the masking effects of these sounds by improving the effective signal-to-sound ratio. In the cases of higher frequency hearing by the bottlenose dolphin (*Tursiops truncatus*), beluga whale (*Delphinapterus leucas*), and killer whale, empirical evidence confirms that masking depends strongly on the relative directions of arrival of sound signals and the masking sound (Bain 1993; Bain 1994; Dubrovskiy 2004). Toothed whales and probably other marine mammals as well, have additional capabilities besides directional hearing that can facilitate detection of sounds in the presence of background sound. There is evidence that some toothed whales can shift the dominant frequencies of their echolocation signals from a frequency range with a lot of ambient sound toward frequencies with less noise (Au 1974; Au 1975; Moore 1990; Thomas 1990; Romanenko 1992; Lesage 1999). A few marine mammal species increase the source levels or alter the frequency of their calls in the presence of elevated sound levels (Dahlheim 1987; Au 1993; Lesage 1993; Lesage 1999; Terhune 1999; Foote 2004; Parks 2007; Holt 2009; Parks 2009).

These data demonstrating adaptations for reduced masking pertain mainly to the very high frequency echolocation signals of toothed whales. There is less information about the existence of corresponding mechanisms at moderate or low frequencies or in other types of marine mammals. For example, Zaitseva et al. (1980) found that, for the bottlenose dolphin, the angular separation between a sound source and a masking noise source had little effect on the degree of masking when the sound frequency is 18 kilohertz, in contrast to the pronounced effect at higher frequencies. Studies have noted directional hearing at frequencies as low as 0.5 to 2 kilohertz in several marine mammals, including killer whales (Richardson et al. 1995c). This ability may be useful in reducing masking at these frequencies.

In summary, high levels of sound generated by the proposed seismic survey activities may act to mask the detection of weaker biologically important sounds by some marine mammals considered in this opinion. This masking is expected to be more prominent for baleen whales given the lower frequencies at which they hear best and produce calls. For toothed whales (e.g., sperm whales), which hear best at frequencies above the predominant ones produced by airguns and may have adaptations to allow them to reduce the effects of masking on higher frequency sounds such as echolocation clicks like other toothed whales mentioned above (e.g., belugas, Au et al. 1985), masking is not expected to be significant for individual marine mammals.

Marine Mammals and Behavioral Responses

We expect the greatest response of marine mammals to airgun array sounds in terms of number of responses and overall impact to be in the form of changes in behavior. ESA-listed individuals may briefly respond to underwater sound by slightly changing their behavior or relocating a short distance. Displacement from important feeding or breeding areas over a prolonged period would likely be more significant for individuals and could affect the population depending on the extent of the feeding area and duration of displacement. This has been suggested for humpback whales along the Brazilian coast as a result of increased seismic survey activity (Parente et al. 2007). Marine mammal responses to anthropogenic sound vary by species, state of maturity, prior exposure, current activity, reproductive state, time of day, and other factors (Ellison et al. 2012; Harris et al. 2018) This is reflected in a variety of aquatic, aerial, and terrestrial animal responses to anthropogenic noise that may ultimately have fitness consequences (NRC 2005a; Francis and Barber 2013; New et al. 2014; Costa et al. 2016; Fleishman et al. 2016). Although some studies are available that address responses of ESA-listed marine mammals considered in this opinion directly, additional studies of other related whales (such as bowhead and gray whales) are relevant in determining the responses expected by species under consideration. Therefore, studies from non-ESA-listed or species outside the action area are also considered here. Animals generally respond to anthropogenic perturbations as they will predators, increasing vigilance, and altering habitat selection (Reep et al. 2011). There is increasing support that this prey-predator-like response is true for animals' response to anthropogenic sound (Harris et al. 2018). Habitat abandonment due to anthropogenic noise exposure has been found in terrestrial species (Francis and Barber 2013). Because of the similarities in hearing anatomy of terrestrial and marine mammals, we expect it possible for ESA-listed marine mammals to behave in a similar manner as terrestrial mammals when they detect a sound stimulus. For additional information on the behavioral responses marine mammals exhibit in response to anthropogenic noise, including non-ESA-listed marine mammal species, see the *Federal Register* notice of the proposed IHA (84 FR 26940), as well as one of several reviews (e.g., Southall et al. 2007c; Gomez et al. 2016).

Several studies have aided in assessing the various levels at which whales may modify or stop their calls in response to sounds for airguns. Whales continue calling while seismic surveys are operating locally (Richardson et al. 1986a; McDonald et al. 1993; McDonald et al. 1995; Greene Jr et al. 1999; Madsen et al. 2002b; Tyack et al. 2003; Nieukirk et al. 2004; Smultea et al. 2004; Jochens et al. 2006). However, humpback whale males increasingly stopped vocal displays on Angolan breeding grounds as received seismic airgun levels increased (Cerchio 2014). Some blue, fin, and sperm whales stopped calling for short and long periods apparently in response to airguns (Bowles et al. 1994; McDonald et al. 1995; Clark and Gagnon 2006). Fin whales (presumably adult males) engaged in singing in the Mediterranean Sea moved out of the area of a seismic survey while airguns were operational, as well as for at least a week thereafter (Castellote et al. 2012a). Dunn and Hernandez (2009) tracked blue whales during a seismic survey on the R/V *Maurice Ewing* in 2007 and did not observe changes in call rates or find evidence of anomalous behavior that they could directly ascribe to the use of airguns at sound levels of approximately less than 145 dB re: 1 μPa (rms) (Wilcock et al. 2014). Blue whales may attempt to compensate for elevated ambient sound by calling more frequently during seismic surveys (Iorio and Clark 2009). Bowhead whale calling rates were found to decrease during migration in the Beaufort Sea when seismic surveys were being conducted (Nations et al. 2009). Calling rates decreased when exposed to seismic airguns at estimated received levels of 116 to

129 dB re: 1 μPa (rms), but did not change at received levels of 99 to 108 dB re: 1 μPa (rms) (Blackwell et al. 2013). A more recent study examining cumulative sound exposure found that bowhead whales began to increase call rates as soon as airgun sounds were detectable, but this increase leveled off at approximate 94 dB re: 1 μPa^2-s over the course of ten minutes (Blackwell et al. 2015). Once sound levels exceeded approximately 127 dB re: 1 μPa^2-s over ten minutes, call rates began to decline and at approximately 160 dB re: 1 μPa^2-s over ten minutes, bowhead whales appeared to cease calling all together (Blackwell et al. 2015). While we are aware of no data documenting changes in North Atlantic right whale vocalization in association with seismic surveys, as mentioned previously, they do shift calling frequencies and increase call amplitude over both long- and short-term periods due to chronic exposure to vessel sound (Parks and Clark 2007; Parks et al. 2007; Parks et al. 2009; Parks et al. 2011; Parks et al. 2012; Tennessen and Parks 2016). Sperm whales, at least under some conditions, may be particularly sensitive to airgun sounds, as they have been documented to cease calling in association with airguns being fired hundreds of kilometers away (Bowles et al. 1994). Other studies have found no response by sperm whales to received airgun sound levels up to 146 dB re: 1 μPa (peak-to-peak) (McCall Howard 1999; Madsen et al. 2002a). For the species considered in this consultation, some exposed individual ESA-listed marine mammals may cease calling or otherwise alter their vocal behavior in response to the R/V *Marcus G. Langseth*'s airgun array during the seismic survey activities. The effect is expected to be temporary and of short duration because the research vessel is constantly moving when the airgun array is active. Animals may resume or modify calling at a later time or location away from the R/V *Marcus G. Langseth*'s airgun array during the course of the proposed seismic survey once the acoustic stressor has diminished.

There are numerous studies of the responses of some baleen whales to airgun arrays. Although responses to lower-amplitude sounds are known, most studies seem to support a threshold of approximately 160 dB re: 1 μPa (rms) (the level used in this opinion to determine the extent of acoustic effects for marine mammals) as the received sound level to cause behavioral responses other than vocalization changes (Richardson et al. 1995c). Activity of individuals seems to influence response (Robertson et al. 2013), as feeding individuals respond less than mother and calf pairs and migrating individuals (Malme et al. 1984b; Malme and Miles 1985; Richardson et al. 1995c; Miller et al. 1999; Richardson et al. 1999; Miller et al. 2005; Harris et al. 2007). Migrating bowhead whales show strong avoidance reactions to exposures to received sound levels of 120 to 130 dB re: 1 μPa (rms) at distances of 20 to 30 kilometers (10.8 to 16.2 nautical miles), but only changed dive and respiratory patterns while feeding and showed avoidance at higher received sound levels (152 to 178 dB re: 1 μPa [rms]) (Richardson et al. 1986b; Ljungblad et al. 1988; Richardson et al. 1995c; Miller et al. 1999; Richardson et al. 1999; Miller et al. 2005; Harris et al. 2007). Nations et al. (2009) also found that bowhead whales were displaced during migration in the Beaufort Sea during active seismic surveys. In fact, as mentioned previously, the available data indicate that most, if not all, baleen whale species exhibit avoidance of active seismic airguns (Gordon et al. 2003; Stone and Tasker 2006; Potter et al. 2007; Southall et al. 2007c; Barkaszi et al. 2012a; Castellote et al. 2012b; NAS 2017; Stone et al. 2017). Despite the above observations and exposure to repeated seismic surveys, bowhead whales continue to return to summer feeding areas and, when displaced, appear to re-occupy within a day (Richardson et al. 1986b). We do not know whether the individuals exposed in these ensonified areas are the same returning or whether though they tolerate repeat exposures, they may still experience a stress response. However, we expect the presence of the PSOs and the shut-down that will occur if a marine mammal were present in the exclusion zone that are part of the proposed action will lower the likelihood that marine mammals will be exposed to significant sound levels from the airgun array.

Gray whales respond similarly to seismic survey sounds as described for bowhead whales. Gray whales discontinued feeding and/or moved away at received sound levels of 163 dB re: 1 μPa (rms) (Malme et al. 1984b; Malme and Miles 1985; Malme et al. 1986; Malme et al. 1987; Würsig et al. 1999; Bain and Williams 2006; Gailey et al. 2007; Johnson et al. 2007a; Meier et al. 2007; Yazvenko et al. 2007). Migrating gray whales began to show changes in swimming patterns at approximately 160 dB re: 1 μPa (rms) and slight behavioral changes at 140 to 160 re: 1 μPa (rms) (Malme et al. 1984a; Malme and Miles 1985). As with bowhead whales, habitat continues to be used despite frequent seismic survey activity, but long-term effects have not been identified, if they are present at all (Malme et al. 1984a). Johnson et al. (2007b) reported that gray whales exposed to airgun sounds during seismic surveys off Sakhalin Island, Russia, did not experience any biologically significant or population level effects, based on subsequent research in the area from 2002 through 2005. Furthermore, when strict mitigation measures, such as those that will be required in the IHA by the NMFS Permits and Conservation Division, are taken to avoid conducting seismic surveys during certain times of the year when most gray whales are expected to be present, gray whales may not exhibit any noticeable behavioral responses to seismic survey activities (Gailey et al. 2016).

Humpback whales exhibit a pattern of lower threshold responses when not occupied with feeding. Migrating humpbacks altered their travel path (at least locally) along Western Australia at received levels as low as 140 dB re: 1 μPa (rms) when females with calves were present, or 7 to 12 kilometers (3.8 to 6.5 nautical miles) from the acoustic source (McCauley et al. 1998; McCauley et al. 2000b). A startle response occurred as low as 112 dB re: 1 μPa (rms). Closest approaches were generally limited to 3 to 4 kilometers (1.6 to 2.2 nautical miles), although some individuals (mainly males) approached to within 100 meters (328.1 feet) on occasion where sound levels were 179 dB re: 1 μPa (rms). Changes in course and speed generally occurred at estimated received levels of 157 to 164 dB re: 1 μPa (rms). Similarly, on the east coast of Australia, migrating humpback whales appear to avoid seismic airguns at distances of 3 kilometers (1.6 nautical miles) at levels of 140 dB re: 1 μPa^2-second. A recent study examining the response of migrating humpback whales to a full 51,291.5 cubic centimeters (3,130 cubic inch) airgun array found that humpback whales exhibited no abnormal behaviors in response to the active airgun array and, while there were detectible changes in respiration and diving, these were similar to those observed when baseline groups (i.e., not exposed to active sound sources) were joined by another humpback whale (Dunlop et al. 2017). While some humpback whales were also found to reduce their speed and change course along their migratory route, overall these results suggest that the behavioral responses exhibited by humpback whales are unlikely to have significant biological consequences for fitness (Dunlop et al. 2017). Feeding humpback whales appear to be somewhat more tolerant. Humpback whales off the coast of Alaska startled at 150 to 169 dB re: 1 μPa (rms) and no clear evidence of avoidance was apparent at received levels up to 172 dB re: 1 μPa (rms) (Malme et al. 1984b; Malme et al. 1985). Potter et al. (2007) found that humpback whales on feeding grounds in the Atlantic Ocean did exhibit localized avoidance to airgun arrays. Among humpback whales on Angolan breeding grounds, no clear difference was observed in encounter rate or point of closest approach during seismic versus non-seismic periods (Weir 2008).

Observational data are sparse for specific baleen whale life histories (breeding and feeding grounds) in response to airguns. Available data support a general avoidance response. Some fin and sei whale sighting data indicate similar sighting rates during seismic versus non-seismic periods, but sightings tended to be further away and individuals remained underwater longer (Stone 2003; Stone and Tasker 2006; Stone et al. 2017). Other studies have found at least small differences in sighting rates (lower during seismic survey activities), as well as whales being more distant during seismic survey activities (Moulton and Miller 2005b). When spotted at the average sighting distance, individuals will have likely been exposed to approximately 169 dB re: 1 μPa (rms) (Moulton and Miller 2005a).

Sperm whale response to airguns has thus far included mild behavioral disturbance (temporarily disrupted foraging, avoidance, cessation of vocal behavior) or no reaction. Several studies have found sperm whales in the Atlantic Ocean to show little or no response (Davis et al. 2000; Stone 2003; Moulton and Miller 2005b; Madsen et al. 2006; Stone and Tasker 2006; Weir 2008; Miller et al. 2009; Stone et al. 2017). Detailed study of sperm whales in the Gulf of Mexico suggests some alteration in foraging from less than 130 to 162 dB re: 1 μPa peak-to-peak, although other behavioral reactions were not noted by several authors (Gordon et al. 2004; Gordon et al. 2006; Jochens et al. 2006; Madsen et al. 2006; Winsor and Mate 2006). This has been contradicted by other studies, which found avoidance reactions by sperm whales in the Gulf of Mexico in response to seismic ensonification (Mate et al. 1994; Jochens 2003; Jochens and Biggs 2004). Johnson and Miller (2002) noted possible avoidance at received sound levels of 137 dB re: 1 μPa. Other anthropogenic sounds, such as pingers and sonars, disrupt behavior and vocal patterns (Watkins and Schevill 1975b; Watkins et al. 1985; Goold 1999). Miller et al. (2009) found sperm whales to be generally unresponsive to airgun exposure in the Gulf of Mexico, although foraging behavior may have been affected based on changes in echolocation rate and slight changes in dive behavior. Displacement from the area was not observed. Winsor and Mate (2013) did not find a non-random distribution of satellite-tagged sperm whales at and beyond 5 kilometers (2.7 nautical miles) from airgun arrays, suggesting individuals were not displaced or move away from the airgun array at and beyond these distances in the Gulf of Mexico (Winsor and Mate 2013). However, no tagged whales within 5 kilometers (2.7 nautical miles) were available to assess potential displacement within 5 kilometers (2.7 nautical miles) (Winsor and

Mate 2013). In a follow-up study using additional data, Winsor et al. (2017) found no evidence to suggest sperm whales avoid active airguns within distances of 50 kilometers (27 nautical miles). The lack of response by this species may in part be due to its higher range of hearing sensitivity and the low-frequency (generally less than 200 Hertz) pulses produced by seismic airguns (Richardson et al. 1995c). However, sperm whales are exposed to considerable energy above 500 Hertz during the course of seismic surveys (Goold and Fish 1998), so even though this species generally hears at higher frequencies, this does not mean that it cannot hear airgun sounds. Breitzke et al. (2008) found that source levels were approximately 30 dB re: 1 μPa lower at 1 kilohertz and 60 dB re: 1 μPa lower at 80 kilohertz compared to dominant frequencies during a seismic source calibration. Another odontocete, bottlenose dolphins, progressively reduced their vocalizations as an airgun array came closer and got louder (Woude 2013). Reactions of sperm whales to impulse noise likely vary depending on the activity at time of exposure. For example, in the presence of abundant food or during breeding encounters, toothed whales sometimes are extremely tolerant of noise pulses (NMFS 2010a).

Similar to other marine mammal species, behavioral responses of pinnipeds can range from a mild orienting response, or a shifting attention, to flight and panic. They may react in a number of ways depending on their experience with the sound source that what activity they are engaged in at the time of the exposure. For example, different responses displayed by captive and wild phocid seals to sound judged to be 'unpleasant' have been reported; where captive seals habituated (did not avoid the sound), and wild seals showed avoidance behavior (Götz and Janik 2011). Captive seals received reinforcement during sound playback, while wild seals were exposed opportunistically. These results indicate that motivational state (e.g., reinforcement via food acquisition) can be a factor in whether or not an animal habituates to novel or unpleasant sounds. Captive studies with other pinnipeds have shown a reduction in dive times when presented with qualitatively 'unpleasant' sounds. These studies indicated that the subjective interpretation of the pleasantness of a sound, minus the more commonly studied factors of received sound level and sounds associated with biological significance, can affect diving behavior (Götz and Janik 2011). More recently, a controlled-exposure study was conducted with U.S. Navy California sea lions at the Navy Marine Mammal Program facility specifically to study behavioral reactions (Houser et al. 2013). Animals were trained to swim across a pen, touch a panel, and return to the starting location. During transit, a simulated mid-frequency sonar signal was played. Behavioral reactions included increased respiration rates, prolonged submergence, and refusal to participate, among others. Younger animals were more likely to respond than older animals, while some sea lions did not respond consistently at any level.

Kvadsheim et al. (2010) found that captive hooded seal (*Cystophora cristata*) reacted to 1 to 7 kilohertz sonar signals by moving to the areas of last sound pressure level, at levels between 160 and 170 dB re: 1 μPa. Finneran et al. (2003b) found that trained captive sea lions showed avoidance behavior in response to impulsive sounds at levels above 165 to 170 dB re: 1 μPa (rms). These studies are in contrast to the results of Costa (1993) which found that free-ranging elephant seals showed no change in diving behavior when exposed to very low frequency sounds

(55 to 95 Hertz) at levels up to 137 dB re: 1 μPa (though the received level in this study were much lower (Costa et al. 2003). Similar to behavioral responses of mysticetes and odontocetes, potential behavioral responses of pinnipeds to the proposed seismic survey activities are not expected to impact the fitness of any individual animals as the responses are not likely to adversely affect the ability of the animals to forage, detect predators, select a mate, or reproduce successfully. As noted in (Southall et al. 2007b), substantive behavioral reactions to noise exposure (such as disruption of critical life functions, displacement, or avoidance of important habitat) are considered more likely to be significant if they last more than 24 hours, or recur on subsequent days. Behavioral reactions are not expected to last more than 24 hours or recur on subsequent days such that an animal's fitness could be impacted. That we do not expect fitness consequences is further supported by Navy monitoring of Navy-wide activities since 2006, which has documented hundreds of thousands of marine mammals on training and testing range complexes. Only two instances of overt behavioral change have been observed and there have been no demonstrable instances of injury to marine mammals because of non-impulsive acoustic sources such as low frequency active sonar. We do not expect significant fitness consequences to individual animals to result from instances of behavioral response.

Pinnipeds are not likely to show a strong avoidance reaction to the airgun array sources proposed for use. Visual monitoring from seismic survey vessels has shown only slight (if any) avoidance of airgun arrays by pinnipeds and only slight (if any) changes in behavior. Monitoring work in the Alaskan Beaufort Sea during 1996 through 2001 provided considerable information regarding the behavior of Arctic ice seals exposed to seismic pulses (Harris et al. 2001; Moulton and Lawson 2002). These seismic survey projects usually involved airgun arrays of six to 16 airguns with total volumes of 9,176.8 to 24,580.6 cubic centimeters (560 to 1,500 cubic inches). The combined results suggest that some seals avoid the immediate area around seismic survey vessels. In most survey years, ringed seal (*Phoca hispida*) sightings tended to be farther away from the seismic survey vessel when the airgun arrays were operating than when they were not (Moulton and Lawson 2002). However, these avoidance movements were relatively small, approximately 100 meters (328.1 feet) to a few hundreds of meters, and many seals remained within 100 to 200 meters (328.1 to 656.2 feet) of the trackline as the operating airgun array passed by the animals. Seal sighting rates at the water surface were lower during airgun array operations than during no-airgun periods in each survey year except 1997. Similarly, seals are often very tolerant of pulsed sounds from seal-scaring devices (Mate and Harvey 1987; Jefferson and Curry 1994; Richardson et al. 1995a). However, initial telemetry work suggests that avoidance and other behavioral reactions by two other species of seals to small airgun array sources may at times be stronger than evident to date from visual studies of pinniped reactions to airguns (Thompson et al. 1998).

Elephant seals are unlikely to be affected by short-term variations in prey availability (Costa 1993), as cited in New et al. (2014). We expect the Guadalupe fur seals considered in this opinion to be similarly unaffected. We have no information to suggest animals eliciting a behavioral response (e.g., temporary disruption of feeding) from exposure to the proposed seismic survey activities will be unable to compensate for this temporary disruption in feeding activity by either immediately feeding at another location, by feeding shortly after cessation of acoustic exposure, or by feeding later.

In summary, ESA-listed marine mammals are expected to exhibit a wide range of behavioral responses when exposed to sound fields from the airgun array. Baleen whales are expected to mostly exhibit avoidance behavior, and may also alter their vocalizations. Toothed whales (i.e., sperm whales) are expected to exhibit less overt behavioral changes, but may alter foraging behavior, including echolocation vocalizations. Pinnipeds (i.e., Guadalupe fur seals) are expected to exhibit avoidance and behavioral changes. These responses are expected to be temporary with behavior returning to a baseline state shortly after the sound source becomes inactive or leaves the area.

Marine Mammals and Physical or Physiological Effects

Individual whales exposed to airguns (as well as other sound sources) could experience effects not readily observable such as stress (Romano et al. 2002) that may have adverse effects. Other possible responses to impulsive sound sources like airgun arrays include neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage (Cox et al. 2006; Southall et al. 2007c; Zimmer and Tyack 2007; Tal et al. 2015), but similar to stress, these effects are not readily observable. Importantly, these more severe physical and physiological responses have been associated with explosives and/or mid-frequency tactical sonar, but not seismic airguns. There have been no reported stranding events after NSF surveys. Thus, we do not expect ESA-listed marine mammals to experience any of these more severe physical and physiological responses because of the proposed seismic survey activities.

Stress is an adaptive response and does not normally place an animal at risk. Distress involves a stress response resulting in a biological consequence to the individual. The mammalian stress response involves the hypothalamic-pituitary-adrenal axis being stimulated by a stressor, causing a cascade of physiological responses, such as the release of the stress hormones cortisol, adrenaline (epinephrine), glucocorticosteroids, and others (Thomson and Geraci 1986; St. Aubin and Geraci 1988; St. Aubin et al. 1996; Gulland et al. 1999; Gregory and Schmid 2001; Busch and Hayward 2009). These hormones subsequently can cause short-term weight loss, the liberation of glucose into the blood stream, impairment of the immune and nervous systems, elevated heart rate, body temperature, blood pressure, and alertness, and other responses (Thomson and Geraci 1986; Kaufman and Kaufman 1994; Dierauf and Gulland 2001; Cattet et al. 2003; Elftman et al. 2007; Fonfara et al. 2007; Noda et al. 2007; Mancia et al. 2008; Busch and Hayward 2009; Dickens et al. 2010; Costantini et al. 2011). In some species, stress can also increase an individual's susceptibility to gastrointestinal parasitism (Greer et al. 2005). In highly stressful circumstances, or in species prone to strong "fight-or-flight" responses, more extreme consequences can result, including muscle damage and death (Cowan and Curry 1998; Cowan and Curry 2002; Herraez et al. 2007; Cowan 2008). The most widely-recognized indicator of vertebrate stress, cortisol, normally takes hours to days to return to baseline levels following a significantly stressful event, but other hormones of the hypothalamic-pituitary-adrenal axis may persist for weeks (Dierauf and Gulland 2001). Stress levels can vary by age, sex, season, and health status (St. Aubin et al. 1996; Gardiner and Hall 1997; Hunt et al. 2006; Keay et al. 2006; Romero et al. 2008). For example, stress is lower in immature North Atlantic right whales than adults and mammals with poor diets or undergoing dietary change tend to have higher fecal cortisol levels (Hunt et al. 2006; Keay et al. 2006).

Loud sounds generally increase stress indicators in mammals (Kight and Swaddle 2011). Romano et al. (2004) found beluga whales and bottlenose dolphins exposed to a seismic water gun (up to 228 dB re: 1 μPa m peak-to-peak and single pure tones (up to 201 dB re: 1 μPa) had increases in stress chemicals, including catecholamines, which could affect an individual's ability to fight off disease. During the time following September 11, 2001, shipping traffic and associated ocean noise decreased along the northeastern U.S. This decrease in ocean sound was associated with a significant decline in fecal stress hormones in North Atlantic right whales, providing evidence that chronic exposure to increased noise levels, although not acutely injurious, can produce stress (Rolland et al. 2012). These levels returned to baseline after 24 hours of traffic resuming.

As whales use hearing for communication as a primary way to gather information about their environment, we assume that limiting these abilities, as is the case when masking occurs, will be stressful. We also assume that any individuals exposed to sound levels sufficient to trigger onset of TTS will also experience physiological stress response (NRC 2003b; NMFS 2006b). Finally, we assume that some individuals exposed at sound levels below those required to induce a TTS, but above the 160 dB re: 1 μPa (rms) threshold, will experience a stress response, which may also be associated with an overt behavioral response. However, exposure to sounds from airgun arrays (or fisheries echosounder) are expected to be temporary so we expect any such stress responses to be short-term. Given the available data, animals will be expected to return to baseline state (e.g., baseline cortisol level) within hours to days, with the duration of the stress response depending on the severity of the exposure (i.e., we expect a TTS exposure will result in a longer duration response before returning to a baseline state as compared to exposure to levels below the TTS threshold).

Data specific to cetaceans are not readily available to assess other non-auditory physical and physiological responses to sound. However, based on studies of other vertebrates, exposure to loud sound may also adversely affect reproductive and metabolic physiology (reviewed in Kight and Swaddle 2011). Premature birth and indicators of developmental instability (possibly due to disruptions in calcium regulation) have been found in embryonic and neonatal rats exposed to loud sound. Fish eggs and embryos exposed to sound levels only 15 dB greater than background showed increased mortality and surviving fry and slower growth rates, although the opposite trends have also been found in sea bream. Studies of rats have shown that their small intestine leaks additional cellular fluid during loud sound exposure, potentially exposing individuals to a higher risk of infection (reflected by increases in regional immune response in experimental animals). In addition, exposure to 12 hours of loud sound may alter cardiac tissue in rats. In a variety of response categories, including behavioral and physiological responses, female animals appear to be more sensitive or respond more strongly than males. It is noteworthy that, although various exposures to loud sound appear to have adverse results, exposure to music largely appears to result in beneficial effects in diverse taxa. Clearly, the impacts of even loud sound are complex and not universally negative (Kight and Swaddle 2011). Given the available data, and the short duration of exposure to sounds generated by airgun arrays, we do not anticipate any effects to reproductive and metabolic physiology of ESA-listed marine mammals exposed to these sounds.

It is possible that an animal's prior exposure to sounds from seismic surveys influence its future response. We have little information available to us as to what response individuals will have to future exposures to sources from seismic surveys compared to prior experience. If prior exposure produces a learned response, then this subsequent learned response will likely be similar to or less than prior responses to other stressors where the individual experienced a stress response associated with the novel stimuli and responded behaviorally as a consequence (such as moving away and reduced time budget for other activities like feeding that would otherwise be undertaken) (Andre 1997; André 1997; Gordon et al. 2006). We do not believe sensitization will occur based upon the lack of severe responses previously observed in marine mammals and sea turtles exposed to sounds from seismic surveys, including those conducted by NSF in or near the action area. The proposed action will take place over approximately 37 days; minimizing the likelihood that sensitization will occur. As stated before, we believe that exposed individuals will move away from the sound source, especially in the open ocean of the action area, where we expect species to be transiting.

Marine Mammals and Strandings

There is some concern regarding the coincidence of marine mammal strandings and proximal seismic surveys. No conclusive evidence exists to causally link stranding events to seismic surveys. Suggestions that there was a link between seismic surveys and strandings of humpback whales in Brazil (Engel et al. 2004) were not well founded (Iagc 2004; IWC 2007a). In September 2002, two Cuvier's beaked whales (*Ziphius cavirostris*) stranded in the Gulf of California, Mexico. The R/V *Maurice Ewing* had been operating a 20-airgun array (139,126.2 cubic centimeters [8,490 cubic inch]) 22 kilometers (11.9 nautical miles) offshore at the time that stranding occurred. The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence, as the individuals who happened upon the stranding were ill-equipped to perform an adequate necropsy (Taylor et al. 2004). Furthermore, the small numbers of animals involved and the lack of knowledge regarding the spatial and temporal correlation between the beaked whales and the sound source underlies the uncertainty regarding the linkage between sound sources from seismic surveys and beaked whale strandings (Cox et al. 2006). Numerous studies suggest that the physiology, behavior, habitat relationships, age, or condition of cetaceans may cause them to strand or might pre-dispose them to strand when exposed to another phenomenon. These suggestions are consistent with the conclusions of numerous other studies that have demonstrated that combinations of dissimilar stressors commonly combine to kill an animal or dramatically reduce its fitness, even though one exposure without the other does not produce the same result (Fair and Becker 2000; Moberg 2000; Kerby et al. 2004; Romano et al. 2004; Creel 2005). At present, the factors of airgun arrays from seismic surveys that may contribute to marine mammal strandings are unknown and we have no evidence to lead us to believe that aspects of the airgun array proposed for use will cause marine mammal strandings. The seismic survey will take place in the Northeast Pacific Ocean, and the closest approach to the United States coastline will be approximately 370.1 kilometers (230 miles) from land off Washington and Oregon. If exposed to seismic survey activities, we expect ESA-listed marine mammals will have sufficient space in the open ocean to move away from the sound source and will not be likely to experience exposure to the sound source to the point that animals would strand.

Marine Mammal Response to Multi-Beam Echosounder, Sub-Bottom Profiler, Acoustic Doppler Current Profiler, and Acoustic Release Transponder

We expect ESA-listed marine mammals to experience ensonification from not only the airgun array, but also from the multi-beam echosounder, sub-bottom profiler, and acoustic Doppler current profiler. The multi-beam echosounder, sub-bottom profiler, and acoustic Doppler current profiler used during the seismic survey operate at a frequency of 10.5 to 13 (usually 12) kilohertz, 3.5 kilohertz, and 75 kilohertz, respectively. These frequencies are within the functional hearing range of baleen whales (7 Hertz to 35 kilohertz), such as blue, fin, humpback, and sei whales, as well as sperm whales (150 Hertz to 160 kilohertz) (NOAA 2018). We expect that these mapping systems will produce harmonic components in a frequency range above and below the center frequency similar to other commercial sonars (Deng 2014). Although Todd et al. (1992) found that mysticetes reacted to sonar sounds at 3.5 kilohertz within the 80 to 90 dB re: 1 μPa range, it is difficult to determine the significance of this because the sound source was a signal designed to be alarming and the sound level was well below typical ambient noise. Goldbogen et al. (2013) found blue whales to respond to 3.5 to 4 kilohertz mid-frequency sonar at received levels below 90 dB re: 1 μPa. Responses included cessation of foraging, increased swimming speed, and directed travel away from the source (Goldbogen 2013). Hearing is poorly understood for ESA-listed baleen whales, but it is assumed that they are most sensitive to frequencies over which they vocalize, which are much lower than frequencies emitted by the multi-beam echosounder, sub-bottom profiler, acoustic Doppler current profiler, and acoustic release transponder (Richardson et al. 1995e; Ketten 1997).

Assumptions for humpback and sperm whale hearing are much different than for ESA-listed baleen whales. Humpback and sperm whales vocalize between 3.5 to 12.6 kilohertz and an audiogram of a juvenile sperm whale provides direct support for hearing over this entire range (Payne 1970; Winn et al. 1970a; Levenson 1974; Tyack 1983a; Tyack and Whitehead 1983; Payne and Payne 1985; Silber 1986a; Thompson et al. 1986a; Carder and Ridgway 1990;

Weilgart and Whitehead 1993; Goold and Jones 1995; Richardson et al. 1995e; Weilgart and Whitehead 1997b; Au 2000; Frazer and Mercado 2000; Erbe 2002a; Au et al. 2006a; Weir et al. 2007). The response of a blue whale to 3.5 kilohertz sonar supports this species' ability to hear this signal as well (Goldbogen 2013). Maybaum (1990a; 1993) observed that Hawaiian humpback whales moved away and/or increased swimming speed upon exposure to 3.1 to 3.6 kilohertz sonar. Kremser et al. (2005) concluded the probability of a cetacean swimming through the area of exposure when such sources emit a pulse is small. The animal would have to pass the transducer at close range and be swimming at speeds similar to the vessel in order to receive the multiple pulses that might result in sufficient exposure to cause TTS. Sperm whales have stopped vocalizing in response to six to 13 kilohertz pingers, but did not respond to 12-kilohertz echosounders (Backus and Schevill 1966; Watkins and Schevill 1975a; Watkins 1977). Sperm whales exhibited a startle response to 10-kilohertz pulses upon exposure while resting and feeding, but not while traveling (Andre 1997; André 1997).

Investigations stemming from a 2008 stranding event in Madagascar indicated a 12 kilohertz multi-beam echosounder, similar in operating characteristics as that proposed for use aboard the R/V *Marcus G. Langseth*, suggest that this sonar played a significant role in the mass stranding of a large group of melon-headed whales (*Peponocephala electra*) (Southall 2013). Although pathological data suggest a direct physical effect is lacking and the authors acknowledge that, while the use of this type of sonar is widespread and commonplace globally without noted incidents (like the Madagascar stranding), all other possibilities were either ruled out or believed to be of much lower likelihood as a cause or contributor to stranding compared to the use of the multi-beam echosounder (Southall 2013). This incident highlights the caution needed when interpreting effects that may or may not stem from anthropogenic sound sources, such as the R/V *Marcus G. Langseth*'s use of the multi-beam echosounder, sub-bottom profiler, and acoustic Doppler current profiler. Although effects such as the stranding in Madagascar have not been documented for ESA-listed species, the combination of exposure to this stressor with other factors, such as behavioral and reproductive state, oceanographic and bathymetric conditions, movement of the source, previous experience of individuals with the stressor, and other factors may combine to produce a response that is greater than would otherwise be anticipated or has been documented to date (Ellison et al. 2012; Francis 2013).

Although navigational sonars are operated routinely by thousands of vessels around the world, strandings have not been correlated to use of these sonars. Stranding events associated with the operation of naval sonar suggest that mid-frequency sonar sounds may have the capacity to cause serious impacts to marine mammals. The sonars proposed for use by the R/V *Marcus G. Langseth* differ from sonars used during naval operations, which generally have a longer pulse duration and more horizontal orientation than the more downward-directed multi-beam echosounder. The sound energy received by any individuals exposed to the multi-beam echosounder, sub-bottom profiler, and acoustic Doppler current profiler sound sources during the proposed seismic survey activities is lower relative to naval sonars, as is the duration of exposure. The area of possible influence for the multi-beam echosounder, sub-bottom profiler, acoustic Doppler current profiler, and acoustic release transponder is also much smaller, consisting of a narrow zone close to and below the source vessel. Because of these differences, we do not expect these systems to contribute to a stranding event on the part of ESA-listed marine mammals exposed to sound from operation of these systems during the proposed action.

We do not expect appreciable masking of blue, fin, humpback, sei, or sperm whales communication to occur due to the multi-beam echosounder, sub-bottom profiler, and acoustic Doppler current profiler's signal directionality, low duty cycle, and brief period when an individual could be within their beam. These factors were considered when Burkhardt et al. (2013) estimated the risk of injury from multi-beam echosounder was less than three percent that of vessel strike. Behavioral responses to the multi-beam echosounder, sub-bottom profiler, and acoustic Doppler current profiler are likely to be similar to the pulsed sources associated with the rest of the equipment operating during the seismic surveys if received at the same levels. We do not expect hearing impairment such as TTS and other physical effects if the animal is in the area while these equipment are operating, as it would have to pass the transducers at close range in order to be subjected to sound levels that could cause injurious effects.

10.2.2.2 Potential Responses of Sea Turtles to Acoustic Sources

As with marine mammals, ESA-listed sea turtles may exhibit a variety of responses to sound fields associated with seismic survey activities. Below we review what is known about the following responses that sea turtles may exhibit (reviewed in Nelms et al. 2016):

- Hearing threshold shifts;
- Behavioral responses; and
- Non-auditory physical or physiological effects.

To our knowledge, strandings of sea turtles in association with anthropogenic sound has not been documented, and so no such stranding response is expected. In addition, masking is not expected to affect sea turtles because they are not known to rely heavily on acoustics for life functions (Popper et al. 2014b; Nelms et al. 2016).

Acoustic Thresholds

In order to estimate exposure of ESA-listed sea turtles to sound fields generated by the airgun arrays that will be expected to result in a response, we relied on the available scientific literature. Currently, the best available data come from studies by O'Hara and Wilcox (1990) and McCauley et al. (2000a), who experimentally examined behavioral responses of sea turtles in response to airgun arrays. O'Hara and Wilcox (1990) found that loggerhead turtles exhibited avoidance behavior at estimated sound levels of 175 to 176 dB re: 1 μPa (rms) (or slightly less) in a shallow canal. McCauley et al. (2000a) reported a noticeable increase in swimming behavior for both green and loggerhead turtles at received levels of 166 dB re: 1 μPa (rms). At 175 dB re: 1 μPa (rms), both green and loggerhead turtles displayed increased swimming speed and increasingly erratic behavior (McCauley et al. 2000a). Based on these data, we assume that sea turtles will exhibit a behavioral response when exposed to received levels of 175 dB re: 1 μPa (rms) and higher, and so use this threshold to estimate the number of instances of exposure that will result in harassment response. The predicted distances to which sound levels of 175 dB re: 1 μPa (rms) will be received from the single (40 cubic inch), 36 airgun arrays for sea turtles during the seismic activities were presented in Table 3. To summarize, the predicted distances to the 175 dB re: 1 μPa (rms) threshold in shallow, intermediate, and deep waters are 3,924 meters, 2,542 meters, and 1,864 meters, respectively.

We have determined that PTS for sea turtles is highly unlikely to occur. For sea turtles, the thresholds for PTS are 204 dB re 1 $\mu Pa^2 \cdot s$ $SEL_{cum;}$ and 232 dB re: 1 μPa SPL (0-pk). With a source level at the frequency of greatest energy, which is within the sensitive hearing range of sea turtles, the animal will almost have to be directly under the sound source exactly when it fires. Further, PTS may not ever be realized at close distances due to near-field interactions. The airgun array will be shut down if a leatherback sea turtle is about to enter the 100 meter exclusion zone; the calculated isopleth distance to the PTS threshold for sea turtles is 20.5 meters. In addition, the overall density of sea turtles in the action area will be relatively low (0.000114 #/km^2), further decreasing the chances of PTS occurring. Thus, we believe the only responses of leatherback sea turtles will be behavioral and assess the consequences of these responses in our risk analysis.

Sea Turtles and Hearing Thresholds

Like marine mammals, if exposed to loud sounds sea turtles may experience TTS and/or PTS. Although all sea turtle species exhibit the ability to detect low frequency sound in studies, the potential effects of exposure to loud sounds on sea turtle biology remain largely unknown (Samuel et al. 2005; Nelms et al. 2016). Few data are available to assess sea turtle hearing, let alone the effects sound sources from seismic surveys may have on their hearing potential. The only study which addressed sea turtle TTS was conducted by Moein et al. (1994), in which a loggerhead turtle experienced TTS upon multiple exposures to an airgun in a shallow water enclosure, but recovered full hearing sensitivity within one day.

As with marine mammals, we assume that sea turtles will not move towards a sound source that causes them stress or discomfort. Some experimental data suggest sea turtles may avoid seismic sound sources (Moein et al. 1994; McCauley et al. 2000b; McCauley et al. 2000c), but monitoring reports from seismic surveys in other regions suggest that some sea turtles do not avoid airguns and were likely exposed to higher levels of pulses from seismic airgun arrays (Smultea and Holst 2003). For this reason, mitigation measures will be implemented to limit sea turtle exposure at 100 meters (328.1 feet) through the use of observers and shutdowns. In most cases, we expect sea turtles will move away from sounds produced by the airgun array. Although data on the precise sound levels that can result in TTS or PTS are lacking for sea turtles and the effectiveness of mitigation measures such as those that will be implemented as part of the proposed action is not fully understood, we do not expect the vast majority of sea turtles present in the action area to be exposed to sound levels that will result in TTS or PTS. For those individuals that experience TTS, the available data suggest hearing will return to normal within days of the exposure (Moein et al. 1994).

Sea Turtles and Behavioral Responses

As with ESA-listed marine mammals, it is likely that sea turtles will exhibit behavioral responses in the form of avoidance. We do not have much information on how sea turtles will respond, but we present the available information. Behavioral responses to human activity have been investigated for only a few species of sea turtles: green and loggerhead (O'Hara and Wilcox 1990; McCauley et al. 2000a); and leatherback, loggerhead, olive ridley, and 160 unidentified turtles (hardshell species) (Weir 2007). The work by O'Hara and Wilcox (1990) and McCauley et al. (2000a) reported behavioral changes of sea turtles in response to seismic airgun arrays. These studies formed the basis for our 175 dB re: 1 μPa (rms) threshold for determining when sea turtles could experience behavioral or injurious effects due to sound exposure because at and above this level loggerhead turtles were observed to exhibit avoidance behavior, increased swimming speed, and erratic behavior. Loggerhead turtles have also been observed to move towards the surface upon exposure to an airgun (Lenhardt et al. 1983; Lenhardt 1994). In contrast, loggerhead turtles resting at the ocean surface were observed to startle and dive as an active seismic source approached them, with the responses decreasing with increasing distance from the source (Deruiter and Larbi Doukara 2012). Some of these animals may have reacted to the vessel's presence rather than the sound source (Deruiter and Larbi Doukara 2012). Monitoring reports from seismic surveys show that some sea turtles move away from approaching airgun arrays, although other sea turtles approach active airgun arrays within 10 meters (32.8 feet) with minor behavioral responses (Holst et al. 2005c; Smultea et al. 2005; Holst et al. 2006; NMFS 2006c; NMFS 2006a; Holst and Smultea 2008a).

Observational evidence suggests that sea turtles are not as sensitive to sound as are marine mammals and behavioral changes are only expected when sound levels rise above received sound levels of 175 dB re: 1 μPa (rms). If exposed at such sound levels, based on the available data, we anticipate some change in swimming patterns. Some sea turtles may approach the active airgun array, but we expect them to eventually turn away in order to avoid the active airgun array. As such, we expect temporary displacement of exposed individuals from some portions of the action area while the R/V *Marcus G. Langseth* transits through because of behavioral responses to sound sources.

Sea Turtles and Physical or Physiological Effects

Direct evidence of seismic sound causing stress is lacking in sea turtles. However, animals often respond to anthropogenic stressors in a manner that resembles a predator-prey response (Harrington and Veitch 1992; Lima 1998; Gill et al. 2001; Frid and Dill 2002; Frid 2003; Beale and Monaghan 2004; Romero 2004; Harris et al. 2018). As predators generally induce a stress response in their prey (Lopez 2001; Dwyer 2004; Mateo 2007), we assume that sea turtles experience a stress response if exposed to loud sounds from airgun arrays. Individuals may experience a stress response at levels lower than approximately 175 dB re: 1 μPa (rms), but data are lacking to evaluate this possibility. Therefore, we follow the best available evidence identifying a behavioral response as the point at which we also expect a significant stress response.

Sea Turtles Response to Multi-Beam Echosounder, Sub-Bottom Profiler, Acoustic Doppler Current Profiler, and Acoustic Release Transponder

Sea turtles do not possess a hearing range that includes frequencies emitted by the multi-beam echosounder (10.5 to 13 [usually 12] kilohertz), sub-bottom profiler (3.5 kilohertz), acoustic Doppler current profiler (75 kilohertz), and acoustic release transponder (8 to 13 kilohertz). Therefore, ESA-listed sea turtles are not expected to detect these sounds even if they are exposed and are not expected to respond to them.

10.2.2.3 Potential Response of Fishes to Acoustic Sources

Airguns are characterized as impulsive sounds. Possible effects for fish from impulsive sounds can be auditory (hearing impairments) or non-auditory (e.g., tissue effects, injury, barotrauma). There have been several documented effects to fish from seismic airguns, including:

- Hearing impairment or physical damage to fish ears;
- Barotrauma;
- Physiological stress responses;
- Masking; and
- Behavioral responses (displacement.

We do not expect mortality to occur for fishes exposed to the seismic airguns. A study examining the effects of a single airgun pulse on pallid sturgeon (*Scaphirhynchus albus*) found no mortality or lethal injury, but the authors pointed out that the effects of multiple exposures were still unknown (Popper et al. 2016).

Ensonified areas that are large and are subject to repeated blasts by the airgun array may impact ESA-listed fishes to a different degree than would other smaller or temporary impulsive sound sources (e.g., pile driving). For injury, the distance to the threshold for fish is 616 meters. Fish may not be able to leave the area at all or quickly enough to get to a quieter place and avoid the effects of the airguns (Popper and Casper 2011). The shot interval is 37.5 meters, and the R/V *Marcus G. Langseth* will conduct the survey while traveling at 4.2 knots per hour (about 7.8 kilometers per hour). The airgun blasts would occur 208 times in an hour.

Displacement of ESA-listed fishes, particularly Chinook, could be problematic for Southern Resident killer whales. If the proposed action causes Chinook to disperse and they become more difficult for the Southern Resident killer whales to find while foraging, causing Southern Resident killer whales to expend more energy, and perhaps a caloric deficit, leading to fitness consequences for individual animals. If displacement of ESA-listed fishes (or non-listed fish prey species) occurs in coastal Oregon, we are not concerned about indirect effects to Southern Resident killer whales through reduced foraging opportunities because we do not expect the

Southern Resident killer whales to be in those locations. Furthermore, while there is evidence to show that fish can be displaced from an area after seismic airgun operations (Skalski et al. 1992; Slotte et al. 2004), we do not expect fish to be displaced for more than a few days. That the survey will shoot the tracklines and then move on from that area (as opposed to shooting the same area in a lawnmower pattern) lends support to our belief that fish will return to the area within a few days after the survey concludes in an area. As a result, we consider the overall risk to Southern Resident killer whales from indirect effects to ESA-listed Chinook and other salmonids to be reduced.

The revised tracklines off the coast of Washington and Vancouver Island extend to the 100-meter isobaths, and thus do not cover the entirety of the continental shelf. For our analysis, we assumed that the habitat areas for Pacific salmonids was waters out to 200 meters deep. We would expect displacement of fish in those areas, and that fish would return to normal behavior and pre-survey distribution after a few days.

Because sound generated from the survey is brief (i.e., the survey would occur in continental shelf waters over the course of about three days), long-term effects on fish behavior are unlikely. The location of the tracklines in continental shelf waters is also spread out over the action area such that rather short portions of the continental shelf tracklines would be surveyed at one time. The survey would take place over a large action area, with the R/V *Marcus G. Langseth* conducting seismic activities over a trackline then proceeding to others. Thus we expect a single area to be ensonified only once during the entire action. Similarly, long periods of masking are unlikely from airgun activity for fishes, although some brief masking periods could occur and fishes may avoid the area of disturbance. Thus, most physiological stress and behavioral effects are expected to be temporary and of a short duration, and stress levels and behavior would return to normal after cessation of the airgun operation.

Acoustic Thresholds

Impulsive sound sources such as airguns are known to injure or kill fishes or elicit behavioral responses. For airguns, NMFS analyzed impacts from sound produced by airguns using the recommendations consistent with *ANSI Guidelines* (Popper et al. 2014b). These dual metric criteria—peak pressure and cumulative sound exposure level (SEL_{cum})—are used to estimate zones of effects related to mortality and injury from airgun exposure. NMFS assumes that a specified effect will occur when either metric is met or exceeded.

In the 2014 *ANSI Guidelines*, airgun thresholds are derived from the thresholds developed for impact pile-driving exposures (Halvorsen et al. 2011; Halvorsen et al. 2012b; Halvorsen et al. 2012c). This use of a dual metric criteria is consistent with the current impact hammer criteria NMFS applies for fishes with swim bladders (FHWG 2008; Stadler and Woodbury 2009). The interim criteria developed by the Fisheries Hydroacoustic Working Group include dual metric criteria wherein the onset of physical injury will be expected if either the peak SPL exceeds 206 dB re: 1 μPa, or the SEL_{cum}, exceeds 187 dB re: 1 μPa^2-s for fish two grams or larger, or 183 dB 1 μPa^2-s for fish smaller than two grams. However, at the same time the interim criteria were developed, very little information was available from airgun exposures. As such, it is also often applied to other impulsive sound sources. The 2008 interim criteria did not specifically separate thresholds according to severity of hearing impairment such as TTS to recoverable injury to mortality, which was done in the 2014 *ANSI Guidelines*. The 2008 interim criteria also do not differentiate between fish with swim bladders and those without, despite the presence of a swim bladder affecting hearing capabilities and fish sensitivity to sound. The 2008 interim criteria based the lower SEL_{cum} thresholds (187 dB re: 1 μPa^2-s and 183 dB re: 1 μPa^2-s) upon when TTS or minor injuries will be expected to occur. Therefore, these criteria establish the starting point when the whole spectrum of potential physical effects may occur for fishes, from TTS to minor, recoverable injury, up to lethal injury (i.e., either resulting in either instantaneous or delayed mortality). Because some generalized groupings of fish species can be made regarding what is currently known about fish hearing sensitivities (Popper and Hastings 2009; Casper et al. 2012b; Popper et al. 2014b) and influence of a swim bladder, and the fact that none of the ESA-listed Pacific salmonids or green sturgeon in the action area have a swim bladder associated with hearing (and eulachon do not have swim bladders), our analysis of ESA-listed fishes considered in this consultation is focused upon fishes with swim bladders not used in hearing. Southern DPS eulachon is the only ESA-listed fish species considered in this opinion that does not have a swim bladder. Therefore, for eulachon we used the criteria (187/206 dB peak SPL criteria for injury and TTS) for fish with swim bladders as it is likely conservative for this species.

Categories and descriptions of hearing sensitivities are further defined in this document (Popper and N. 2014) as the following[22]:

- Fishes with a swim bladder that is not involved in hearing, lack hearing specializations and primarily detect particle motion at frequencies below 1 kilohertz include all Pacific salmonid species and green sturgeon.

Criteria and thresholds to estimate TTS in fishes exposed to sound produced by airguns are greater than 186 SEL_{cum}[23]. Exposure to sound produced from airguns at a cumulative sound exposure level of 186 dB (re: 1 μPa^2-s) has resulted in TTS in fishes (Popper et al. 2005a).[24]

For the National Science Foundation and L-DEO's seismic survey activities, airgun thresholds for fishes with swim bladders not involved in hearing are 210 SEL_{cum} and greater than 207

[22] The 2014 ANSI Guidelines provide distinctions between fish with and without swim bladders and fish with swim bladders involved in hearing. None of the ESA-listed fish species considered in this consultation have swim bladders involved with their hearing abilities (e.g., Pacific salmonids and green sturgeon), but eulachon do not have swim bladders. Thus, we simplified the distinction to fishes with swim bladders.

[23] Notes: TTS = Temporary Threshold Shift, SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micro Pascal squared seconds [dB re 1 µPa2-s]), NC = effects from exposure to sound produced by airguns is considered to be unlikely, therefore no criteria are reported, > indicates that the given effect would occur above the reported threshold.

[24] This is also slightly more conservative than the 2008 interim pile driving criteria of 187 SEL_{cum}.

SPL_{peak} for onset of mortality and 203 SEL_{cum} and greater than 207 SPL_{peak} for onset of injury.[25] Criteria and thresholds to estimate TTS in fishes exposed to sound produced by airguns are greater than 186 SEL_{cum}.[26] Exposure to sound produced from airguns at a cumulative sound exposure level of 186 dB (re: 1 μPa^2-s) has resulted in TTS in fishes (Popper et al. 2005a).[27] As noted above, in fish that are two grams or larger, the onset of physical injury is expected when the SEL_{cum}, exceeds 187 dB re: 1 μPa^2-s. For this consultation, we expect that all fish exposed to the proposed action will be greater than two grams, and thus use 187 dB as the threshold for the onset of injury. Fish smaller than two grams would be in their natal rivers, not in the marine environment.

For potential behavioral responses of fishes (i.e., sub-injury) from exposure to anthropogenic sounds, there are no formal criteria yet established. This is largely due to the sheer diversity of fishes, their life histories and behaviors, as well as the inherent difficulties conducting studies related to fish behavior in the wild. The NMFS applies a conservative threshold of 150 dB re: 1 μPa (rms) to assess potential behavioral responses of fishes from acoustic stimuli, described below.

In a study conducted by McCauley et al. (2003b), fish were exposed to airgun arrays and observed to exhibit alarm responses from sound levels of 158 to 163 dB re: 1 μPa. In addition, when the 2008 criteria were being developed, one of the technical panel experts, Dr. Mardi Hastings, recommended a "safe limit" of fish exposure, meaning where no injury will be expected to occur to fishes from sound exposure, set at 150 dB re: 1 μPa (rms) based upon her research (Hastings 1990). This "safe limit" was also referenced in a document investigating fish effects from underwater sound generated from construction (Sonalysts 1997) where the authors mention two studies conducted by Dr. Hastings that noted no physical damage to fishes occurred when exposed to sound levels of 150 dB re: 1 μPa (rms) at frequencies between 100 to 2,000 Hertz. In that same report, the authors noted they also observed fish behavioral responses during sound exposure of 160 dB re: 1 μPa (rms), albeit at very high frequencies. More recently, Fewtrell and McCauley (2012) exposed fishes to airgun sound between 147 to 151 dB SEL, and observed alarm responses in fishes, as well as tightly grouped swimming or fast swimming speeds.

None of the current research available on fish behavioral response to sound make recommendations for a non-injury threshold. The studies mentioned here, as with most data available on behavioral responses to anthropogenic sound for fishes, have been obtained through

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[25] Notes: SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micro Pascal squared seconds [dB re 1 μPa2-s]), SPL_{peak} = Peak sound pressure level (decibel referenced to 1 micro Pascal [dB re: 1 μPa]), > indicates that the given effect would occur above the reported threshold.
[26] Notes: TTS = Temporary Threshold Shift, SEL_{cum} = Cumulative sound exposure level (decibel referenced to 1 micro Pascal squared seconds [dB re 1 μPa2-s]), NC = effects from exposure to sound produced by airguns is considered to be unlikely, therefore no criteria are reported, > indicates that the given effect would occur above the reported threshold.
[27] This is also slightly more conservative than the 2008 interim pile driving criteria of 187 SEL_{cum}.

controlled laboratory studies. In other cases, behavioral studies have been conducted in the field with caged fish. Research on fish behaviors has demonstrated that caged fish do not show normal behavioral responses, which makes it difficult to extrapolate caged fish behavior to wild, unconfined fishes (Hawkins et al. 2014; Popper and Hawkins 2014). It is also important to mention that some of the information regarding fish behavior while exposed to anthropogenic sounds has been obtained from unpublished documents such as monitoring reports, grey literature, or other non-peer reviewed documents with varying degrees of quality. Therefore, behavioral effects from anthropogenic sound exposure remains poorly understood for fishes, especially in the wild. Nonetheless, potential behavioral responses must be considered as an effect of acoustic stressors on ESA-listed fishes. For the reasons discussed, and until new data indicate otherwise, NMFS believes a 150 dB re: 1 μPa (rms) threshold for behavioral responses of fishes is appropriate. This criterion is used as a guideline to establish a sound level where responses of fishes may occur and could be a concern. For ESA-listed fishes, NMFS applies this criterion when considering the life stage affected, and any adverse effects that could occur from behavioral responses such as attentional disruption, which could lead to reduced foraging success, impaired predatory avoidance, leaving protected cover, release of stress hormones affecting growth rates, poor reproductive success rates, and disrupted migration. The thresholds for fishes with swim bladders (injury, TTS, behavioral responses) are summarized in Table 50. Eulachon do not have swim bladders; however, NMFS has not come to a consensus on thresholds for fishes without swim bladders. As a result, in the absence of that information, we use the thresholds shown in Table 58 and Table 59 for eulachon as well.

Table 57. Thresholds for fishes with swim bladders not associated with hearing exposed to sound produced by airguns.

Onset of Injury	TTS	Behavioral Responses
203 SEL_{cum} and greater than 206 SPL_{peak}	Greater than 187 SEL_{cum}	150 dB re: 1 μPa (rms)

We calculated the distances (isopleths) at which we expect the onset of injury to occur for fish during the proposed action (Table 59). Currently, NMFS does not have agreed-upon thresholds for the onset of mortality in fish due to sound from airguns.

Table 58. Distances (meters) for onset of injury and TTS for fishes with swim bladders not associated with hearing.

TTS Onset of Isopleth (meters)	Injury Onset Isopleth (meters)
187 SEL_{cum} 3,211	206 SPL_{peak} 230.1

In addition to sound pressure levels, we also considered effects from particle motion of fish. Fishes within the action area such as salmonids have a swim bladder that is distant from the ear and does not contribute to sound pressure reception. These fishes are primarily particle motion detectors. Particle motion is the back-and-forth motion of the component particles of the medium, measured as the particle displacement, velocity, or acceleration. While it is clear that the use of particle motion for establishing criteria is something that should be done in the future, the lack of data on how particle motion impacts fishes, as well as the lack of easily used methods to measure particle motion, currently precludes the evaluation of particle motion in our acoustic effects analysis (Hawkins et al. 2020).

Hearing Impairment (TTS) or Physical Damage to Ears

ESA-listed fishes may experience TTS or permanent injury as a result of seismic activities in the action area. There have been numerous studies conducted on the effects of seismic airguns on fish hearing. One study focusing on pink snapper (*Pristipomoides filamentosus*) kept in cages while a seismic airgun fired as close as 5 to 15 meters away showed physical damage to fish ears, with no evidence of recovery after 58 days (McCauley et al. 2003a). Lake chub (*Couesius plumbeus*) and northern pike (*Esox lucius*) exposed to five airgun blasts experienced hearing loss immediately after the exposure, with a return to normal hearing thresholds 18 to 24 hours afterwards (Popper et al. 2005b). A later follow-up study conducted under similar circumstances found no damage to the sensory epithelia in any of the otoloithic end organs in fish subjected to seismic airguns; northern pike and lake chub did exhibit TTS (Song et al. 2008). This is in contrast to other earlier sound exposure studies which did show physical damage to fish ears (Hastings et al. 1996; McCauley et al. 2003a). However, as Song et al. (2008) point out, factors like water depth and the airgun specifications likely make a difference in the degree of effects to fish.

We are unaware of any research demonstrating TTS in the species considered in this opinion (or other fish species with a swim bladder not involved in hearing) from seismic airguns. Coho, Chinook, chum, sockeye salmon, and steelhead all have a swim bladder, but it is not involved in hearing. Green sturgeon have a swim bladder but no known structures in the auditory system that would enhance hearing, and sensitivity (lowest sound detectable at any frequency) is not very great. Although TTS has not been demonstrated in the species groups considered in this opinion, this does not mean it does not occur. Because we know it can occur from other acoustic stressors, we assume it is possible from exposure to a sound stressor caused by seismic airguns. The criteria used for TTS was based upon a conservative value for more sensitive fish species and life stages with swim bladders. If TTS does occur, it would likely co-occur with barotraumas (i.e., non-auditory injury), and therefore would be within the range of other injuries these fishes are likely to experience from airgun blast exposures. None of the ESA-listed fish considered in this opinion (i.e., salmonids, eulachon, or sturgeon) have a hearing specialization or a swim bladder involved in hearing, thus, minimizing the likelihood of each instance of TTS affecting an individual's fitness. Most fish species are able to rely on alternative mechanisms (e.g., sight, lateral line system) to detect prey, avoid predators, spawn, and to orient in the water column (Popper et al. 2014a). Additionally, hearing is not thought to play a role in salmonid migration (e.g., Putnam et al. 2013). TTS is also short-term in duration with fish being able to replace hair cells when they are damaged (Lombarte et al. 1993; Smith et al. 2006). Depending on the severity of the TTS and underlying degree of hair cell damage, a fish would be expected to recover from the impairment over a period of weeks (for the worst degree of TTS).

In summary, because the ESA-listed fish species considered in this opinion are not known to rely on hearing for essential life functions, and any effects from TTS would be short-term and temporary, individuals would be expected to recover with no long-term consequences.

Barotrauma

The term "barotrauma" refers to physical damage to tissues or organs, and occurs when there is a rapid change in pressure that directly affects the body gases in the fish (Board et al. 2011). When the seismic airgun discharges, it causes such a change in pressure. These types of sound pressures cause the swim bladder in a fish to rapidly and repeatedly expand and contract, and pound against the internal organs. This pneumatic pounding may result in hemorrhage and rupture of blood vessels and internal organs, including the swim bladder, spleen, liver and kidneys. External damage has also been documented, evident with loss of scales, hematomas in the eyes, at the base of fins, etc. (e.g., Yelverton et al. 1975; Wiley et al. 1981; Gisiner 1998; Casper et al. 2012b; Halvorsen et al. 2012a). Fishes can survive and recover from some injuries, but in other cases death can be instantaneous, occur within minutes after exposure, or occur several days later.

One study demonstrated barotrauma to juvenile Chinook from pile driving (an impulsive sound like airguns, but one that is stationary rather than mobile) (Halvorsen et al. 2012c). Another study evaluated the ability of juvenile Chinook to recover from barotrauma after exposure to pile driving, which provided evidence that the fish could recover from mild injuries and that exposure would not affect their survival (Casper et al. 2012a).

Physiological Stress

Physiological effects to fishes from exposure to anthropogenic sound are increases in stress hormones or changes to other biochemical stress indicators (e.g., Sverdrup et al. 1994; D'amelio et al. 1999; Wysocki et al. 2006). Physiological responses of fishes to acoustic stressors have been described in greater detail for other acoustics stressors on fishes. Exposure to seismic airguns could cause spikes in stress hormone levels, or alter a fish's natural behavioral patterns. Physiological effects to fishes from exposure to anthropogenic sound are increases in stress hormones or changes to other biochemical stress indicators (e.g., Sverdrup et al. 1994; D'amelio et al. 1999; Wysocki et al. 2006). Fishes may have physiological stress reactions to sounds that they can detect. For example, a sudden increase in sound pressure level or an increase in overall background noise levels can increase hormone levels and alter other metabolic rates indicative of a stress response. Studies have demonstrated elevated hormones such as cortisol, or increased ventilation and oxygen consumption (Pickering 1981; Smith et al. 2004b; Smith et al. 2004a; Hastings and C. 2009; Simpson et al. 2015; Simpson et al. 2016). Although results from these studies have varied, it has been shown that chronic or long-term (days or weeks) exposures to continuous anthropogenic sounds can lead to a reduction in embryo viability (Sierra-Flores et al. 2015b) and decreased growth rates (Nedelec et al. 2015).

Generally, stress responses are more likely to occur in the presence of potentially threatening sound sources such as predator vocalizations or the sudden onset of loud and impulsive sound signals. Stress responses are typically considered to be brief (a few seconds to minutes) if the exposure is short or if fishes habituate or have previous experience with the sound**.** However, exposure to chronic noise sources may lead to more severe effects leading to fitness consequences such as reduced growth rates, decreased survival rates, reduced foraging success, etc. Although physiological stress responses may not be detectable on fishes during sound exposures, NMFS assumes a stress response occurs when other physiological impacts such as injury or hearing loss occur.

Some studies have been conducted that measure changes in cortisol levels in response to sound sources. Cortisol levels have been measured in fishes exposed to vessel noises, predator vocalizations, or other tones during playback experiments**.** Nichols et al. (2015) exposed giant kelpfish (*Heterostichus rostratus*) to vessel playback sounds, and fish increased levels of cortisol were found with increased sound levels and intermittency of the playbacks. Gulf toadfish (*Opsanus beta*) were found to have elevated cortisol levels when exposed to low-frequency dolphin vocalization playbacks (Remage-Healey et al. 2006). Interestingly, the researchers observed none of these effects in toadfish exposed to low frequency snapping shrimp "pops.", indicating what sound the fish may detect and perceive as threats. Daily exposure of a short duration upsweep (a tone that sweeps upward across multiple frequencies) across 100 to 1,000 hertz of Atlantic cod (*Gadus morhua*) to artificial sound elicited a minor cortisol response, and when the broodstock was exposed during the spawning period, egg production and fertilization rates were reduced, leading to a more than 50 percent reduction in viable embryos (Sierra-Flores et al. 2015a). The levels returned to normal within one hour post-exposure, which supports the general assumption that spikes in stress hormones generally return to normal once the sound of concern ceases**.** The proposed action will not take place in the streams where salmonids spawn, so we do not expect to see similar effects in exposed fishes.

Not all research has indicated stress responses resulting in increased hormone levels. Goldfish exposed to continuous (0.1 to 10 kilohertz) sound at a pressure level of 170 dB re 1 μPa for one month showed no increase in stress hormones (Smith et al. 2004b). Similarly, Wysocki et al. (2007) exposed rainbow trout to continuous band-limited noise with a sound pressure level of about 150 dB re 1 μPa for nine months with no observed stress effects. Additionally, the researchers found no significant changes to growth rates or immune systems compared to control animals held at a sound pressure level of 110 dB re 1 μPa.

Other parameters can be an indicator of stress. A study examining the effects of seismic airguns on Atlantic cod and saithe (also known as pollock, *Pollachius virens*) found that cod exhibited a reduced heart rate in response to the particle motion component when the airgun were fired. Saithe did not exhibit alterations in heart rate (Davidsen et al. 2019). Heart rate can be a sensitive indicator of stress, although other components of cardiac output such as stroke volume play a role and would be necessary to fully consider the effects to fish. Based on the variety of responses shown in the studies presented here, it is difficult to definitively say how precisely ESA-listed fish will experience physiological stress upon exposure to airgun noise. However, we cannot rule it out. Individuals exposed may experience responses like increased cortisol levels, but these are expected to be brief, lasing for the duration of exposure while the airguns are operating near exposed fish, and not pose long-term consequences.

Masking

Masking generally results from a sound impeding an animal's ability to hear other sounds of interest. The frequency of the received level and duration of the sound exposure determine the potential degree of auditory masking. Similar to hearing loss, the greater the degree of masking, the smaller the area becomes within which an animal can detect biologically relevant sounds such as those required to attract mates, avoid predators or find prey (Slabbekoorn et al. 2010). Because the ability to detect and process sound may be important for fish survival, anything that may significantly prevent or affect the ability of fish to detect, process or otherwise recognize a biologically or ecologically relevant sound could decrease chances of survival. For example, some studies on anthropogenic sound effects on fishes have shown that the temporal pattern of fish vocalizations (e.g., sciaenids and gobies) may be altered when fish are exposed to sound-masking (Parsons et al. 2009b). This may indicate fish are able to react to noisy environments by exploiting "quiet windows" (e.g., Lugli and Fine 2003) or moving from affected areas and congregating in areas less disturbed by nuisance sound sources. In some cases, vocal compensations occur, such as increases in the number of individuals vocalizing in the area, or increases in the pulse/sound rates produced (Picciulin et al. 2012). Fish vocal compensations could have an energetic cost to the individual, which may lead to a fitness consequence such as affecting their reproductive success or increase detection by predators (Bonacito et al. 2001; Amorin et al. 2002).

Behavioral Responses (*Displacement*)

Behavioral responses could be expected to occur within the ensonified area for other injurious or physiological responses, and perhaps be extended beyond these ranges if a fish could detect the sound at those greater distances. Given that none of the species considered here have any specialized hearing adaptations, and the threshold for TTS is considered conservative for these hearing groups, most behavioral responses would be expected to occur within the ensonified area for injury and TTS.

In general, NMFS assumes that most fish species would respond in a similar manner to air guns as they do to other impulsive sounds like pile driving. These reactions could include startle or alarm responses; quick bursts in swimming speeds, diving, or changes in swimming orientation. In other responses, fish may move from the area or stay and try to hide if they perceive the sound as a potential threat. Other potential changes include reduced predator awareness and reduced feeding effort. The potential for adverse behavioral effects will depend on a number of factors, including the sensitivity to sound, the type and duration of the sound, as well as life stages of fish that are present in the areas affected.

Fish that detect an impulsive sound may respond in "alarm" detected by Fewtrell (2003), or another startle responses may be exhibited. The startle response in fishes is a quick burst of swimming that may be involved in avoidance of predators. A fish that exhibits a startle response may not necessarily be injured, but it is exhibiting behavior that suggests it perceives a stimulus indicating potential danger in its immediate environment. However, fish do not exhibit a startle response every time they experience a strong hydroacoustic stimulus. A study in Puget Sound, Washington suggests that pile driving operations disrupt juvenile salmon behavior (Feist et al. 1992). Though no underwater sound measurements are available from that study, comparisons between juvenile salmon schooling behavior in areas subjected to pile driving/construction and other areas where there was no pile driving/construction indicate that there were fewer schools of fish in the pile-driving areas than in the non-pile driving areas. The results are not conclusive but there is a suggestion that pile-driving operations may result in a disruption in the normal migratory behavior of the salmon in that study, though the mechanisms salmon may use for avoiding the area are not understood at this time.

Because of the inherent difficulties with conducting fish behavioral studies in the wild, data on behavioral responses for fishes is largely limited to caged or confined fish studies, mostly limited to studies using caged fishes and the use of seismic air guns (Lokkeborg et al. 2012). One way that researchers have been evaluating the effects of seismic airguns on fish is through examining fisheries catch rates before and after seismic surveys. There is evidence of fish displacement due to seismic surveys causing decreased catch rates of cod (Løkkeborg and Soldal 1993a). Another study showed that fishing catch rates decreased for haddock (68 percent) and cod (69 percent) within the seismic activity area, with effects observed up to 18 nautical miles from the seismic sound source and greater reductions closer to the sound source (Engås et al. 1996a). Catch rates did not return to normal in the five days after seismic activity ended. The authors also found that the effects of seismic activity were more pronounced on large cod (>60 centimeters) than smaller cod, with smaller cod still caught in the trawls and longlines. The authors hypothesized that this may be due to a size-dependent swimming capability of the larger fish to get away from the seismic sound source, or that the smaller fish are more able to take the bait on the longlines when the larger fish are not present (Engås et al. 1996a). A single airgun that created peak pressures above 186 dB caused a decline of 52.4 percent in rockfish (Sebastes spp.) catch per unit effort compared to control conditions (Skalski et al. 1992). It is important to point out that there has been a wide range of responses of fish catch rates to seismic surveys. In another study in Prudhoe Bay, Alaska, seismic activity changed fish catch rates, increasing catches of some species, and decreasing catches of others (Streever et al. 2016). A study examining reef fish behavior with video cameras during a seismic survey that approached within 0.7 and 6.5 kilometers found that reef fish abundance declined by 78 percent in the evening hours, when fish abundance had been highest. One fish was observed to exhibit a behavioral response by swimming away from a ledge (Paxton et al. 2017). However, another study looking at the response of reef fish to a three-dimensional seismic study found no measurable effect on species richness or abundance (Miller and Cripps 2013). In light of other studies described here, it still remains possible that ESA-listed fishes in the action area could experience displacement or other behavioral responses.

Responses of Marine Mammal, Sea Turtle, and Fish Prey

Seismic surveys may also have indirect, adverse effects on ESA-listed marine mammals, sea turtles, and fishes by affecting their prey (including larval stages) through lethal or sub-lethal damage, stress responses, or alterations in their behavior or distribution. Such prey include fishes (blue, fin, humpback, sei, sperm, Southern Resident killer whales, adult salmon, and Guadalupe fur seals), zooplankton (blue, fin, humpback, and sei whales), cephalopods (sperm whales and Guadalupe fur seals), and other invertebrates such as crustaceans, mollusks, amphipods, isopods, aquatic insects, insect larvae, and jellyfish (blue whales, juvenile salmon, green sturgeon, eulachon, and leatherback sea turtles). In a recent, fairly exhaustive review, Carroll et al. (2017) summarized the available information on the impact seismic surveys have on fishes and invertebrates. In many cases, species-specific information on the prey of ESA-listed marine mammals, sea turtles, and fishes is not available. Until more specific information becomes available, we expect that the prey of ESA-listed marine mammals, leatherback sea turtles, and fishes will respond to sound associated with the proposed action in a similar manner to those fishes and invertebrates described below (information derived from Carroll et al. (2017) unless otherwise noted).

Like with marine mammals and sea turtles, it is possible that seismic surveys can cause physical and physiological responses, including direct mortality, in fishes and invertebrates. In fishes, such responses appear to be highly variable, and depend on the nature of the exposure to seismic survey activities, as well as the species in question. Current data indicate that possible physical and physiological responses include hearing threshold shifts, barotraumatic ruptures, stress responses, organ damage, and/or mortality. For invertebrates, research is more limited, but the available data suggest that exposure to seismic survey activities can result in anatomical damage and mortality in some cases. In crustaceans and bivalves, there are mixed results with some studies suggesting that seismic surveys do not result in meaningful physiological and/or physical effects, while others indicate such effects may be possible under certain circumstances.

Furthermore, even within studies there are sometimes differing results depending on what aspect of physiology one examines (e.g., Fitzgibbon et al. 2017). In some cases, the discrepancies likely relate to differences in the contexts of the studies. For example, in a relatively uncontrolled field study, Parry et al. (2002) did not find significant differences in mortality between oysters that were exposed to a full seismic airgun array and those that were not, but a recent study by Day et al. (2017) in a more controlled setting did find significant differences in mortality between scallops exposed to a single airgun and a control group that received no exposure. However, the increased mortality documented by Day et al. (2017) was not significantly different from the expected natural mortality. All available data on echinoderms suggests they exhibit no physical or physiological response to exposure to seismic survey activities. Based on the available data, we assume that some fishes and invertebrates that serve as prey for ESA-listed marine mammals, sea turtles, and fish may experience physical and physiological effects, including mortality.

There has been research suggesting that that seismic airgun arrays may lead to a significant reduction in zooplankton, including copepods. McCauley et al. (2017) found that the use of a single airgun (approximately 150 cubic inches) led to a decrease in zooplankton abundance by over 50 percent and a two- to three-fold increase in dead adult and larval zooplankton when compared to control scenarios. In addition, effects were found out to 1.2 kilometers (0.6 nautical miles); the maximum distance to which sonar equipment used in the study was able to detect changes in abundance. McCauley et al. (2017) noted that for seismic activities to have a significant impact on zooplankton at an ecological scale, the spatial or temporal scale of the seismic activity must be large in comparison to the ecosystem in question. In particular, three-dimensional seismic surveys, which involve the use of multiple overlapping tracklines to extensively and intensively survey a particular area, are of concern (McCauley et al. 2017). This is in part because, in order for such activities to have a measurable effect, they need to outweigh the naturally fast turnover rate of zooplankton (McCauley et al. 2017). The proposed action takes place over a broad spatial area, with the tracklines spaced far apart and will last for 37 days, meaning that we do not believe that the spatial or temporal scale of the seismic survey is large in relation to the marine environment off the U.S. West Coast.

However, Fields et al. (2019a) has demonstrated different results through a series of control experiments using seismic blasts from two airguns (260 cubic inches) during 2009 and 2010 on the zooplankton *Calanus finmarchicus*. Their data show that seismic blasts have limited effects on the mortality of *C. finmarchicus* within 10 meters (32.8 feet) of the seismic airguns, but there was no measurable impact at greater distances. The study also found significantly higher immediate mortality at distances of <5 meters from the airgun and a higher cumulative mortality (7 days after exposure) at a distance somewhere between 10 and 20 meters from the airgun, and observed no sublethal effects but did see changes in gene expression (Fields et al. 2019b). Furthermore, Fields et al. (2019a) demonstrated that seismic airgun blasts had no effect on the escape response of *C. finmarchicus*. They conclude that the effects of seismic airgun blasts are much less than reported by McCauley et al. (2017).

Given the results from each of these studies, it is difficult to fully assess the exact impact seismic airgun arrays may have on the instantaneous or long-term survivability of zooplankton/krill that are exposed. Furthermore, the energy of the proposed seismic arrays (6,630 cubic inches versus 150 or 260 cubic inches) proposed in this consultation suggests that any copepod or crustacean directly exposed to the seismic airguns (underneath or within five meters [16.4 feet]) would likely suffer mortality to an extent greater than described by McCauley et al. (2017).

Results of McCauley et al. (2017) provide little information on the effects to copepods at the surface because their analyses excluded zooplankton at the surface bubble layer. Given that airguns primarily transmit sound downward, and that those associated with the proposed action will be towed at depths of 12 meters (39 feet), we expect that sounds from airgun array will be relatively low at the surface (i.e., above the airgun array), and greater below the airguns. Krill and copepod prey can be found throughout the water column. Baleen whales will dive to different depths to feed, depending on the locations of dense prey aggregations. The foraging depth dives vary by location, whale species, and, in some cases, by time of day, as whales will follow zooplankton prey vertical diel movements.

Seismic surveys are less likely to have significant effects over a broad area on zooplankton because of their fast growth rate and because of the high turnover rate of zooplankton. We expect ocean currents will circulate zooplankton within the action area within a matter of days to weeks (3 to 39 days; (see Richardson et al. 2017 for simulations based on the results of McCauley et al. 2017 that suggest ocean circulation greatly reduce the impact of seismic surveys on zooplankton at the population level). Richardson et al. (2017) simulated a "typical" seismic survey (60 survey lines in a lawnmower pattern, acquired over 35 days). The seismic activities in the proposed action will last for 37 days, and involve the vessel surveying a given area briefly over several hours then transiting to another area (i.e., survey lines will not be repeatedly shot in a given area as in the lawnmower pattern described in Richardson et al. 2017). While the proposed seismic survey may temporarily alter copepod or krill abundance in the action area, we expect such effects to be temporary because of the design of the survey, the high turnover rate of zooplankton, and ocean circulation that will minimize any effects.

Some evidence has been found for fish mortality resulting from exposure to airguns, and this is limited to close-range exposure to high amplitudes (Falk and Lawrence 1973; Kostyuchenko 1973; Holliday et al. 1987; La Bella et al. 1996; D'Amelio 1999; McCauley et al. 2000b; McCauley et al. 2000c; Bjarti 2002; Hassel et al. 2003; McCauley et al. 2003b; Popper et al. 2005a). Lethal effects, if any, are expected within a few meters of the airgun array (Dalen and Knutsen 1986; Buchanan et al. 2004). We expect that, if fish detect the sound and perceive it as a threat or some other signal that induces them to leave the area, they are capable of moving away from the sound source (e.g., airgun array) if it causes them discomfort. We also expect they will return to the area and be available as prey for marine mammals, leatherback sea turtles, and other fishes.

There are reports showing sub-lethal effects to some fish species from airgun arrays. Several species at various life stages have been exposed to high-intensity sound sources (220 to 242 dB re: 1 μPa) at close distances, with some cases of injury (Booman et al. 1996; McCauley et al. 2003b). Effects from TTS were not found in whitefish at received levels of approximately 175 dB re: 1 $\mu Pa^2 s$, but pike did show 10 to 15 dB of hearing loss with recovery within one day (Popper et al. 2005a). Caged pink snapper (*Pelates spp.*) have experienced PTS when exposed over 600 times to received sound levels of 165 to 209 dB re: 1 μPa peak-to-peak. Exposure to airguns at close range were found to produce balance issues in exposed fry (Dalen and Knutsen 1986). Exposure of monkfish (*Lophius* spp.) and capelin (*Mallotus villosus*) eggs at close range to airguns did not produce differences in mortality compared to control groups (Payne 2009). Salmonid swim bladders were reportedly damaged by received sound levels of approximately 230 dB re: 1 μPa (Falk and Lawrence 1973).

The prey of ESA-listed marine mammals, sea turtles, and fishes may also exhibit behavioral responses if exposed to active seismic airgun arrays. Based on the available data, as reviewed by Carroll et al. (2017), considerable variation exists in how fishes behaviorally respond to seismic survey activities, with some studies indicating no response and other noting startle or alarm responses and/or avoidance behavior. However, no effects to foraging or reproduction have been documented. Similarly, data on the behavioral response of invertebrates suggests that some species may exhibit a startle response, but most studies do not suggest strong behavioral responses. For example, a recent study by Charifi et al. (2017) found that oysters appear to close their valves in response to low frequency sinusoidal sounds. In addition, Day et al. (2017) recently found that when exposed to seismic airgun array sounds, scallops exhibit behavioral responses such as flinching, but none of the observed behavioral responses were considered to be energetically costly. As with marine mammals and sea turtles, behavioral responses by fishes and invertebrates may also be associated with a stress response.

Although received sound levels were not reported, caged *Pelates* spp., pink snapper, and trevally (*Caranx ignobilis*) generally exhibited startle, displacement, and/or grouping responses upon exposure to airguns (Fewtrell 2013a). These responses generally persisted for several minutes, although subsequent exposures of the same individuals did not necessarily elicit a response (Fewtrell 2013a).

Startle responses were observed in rockfish at received airgun levels of 200 dB re: 1 μPa 0-to-peak and alarm responses at greater than 177 dB re: 1 μPa 0-to-peak (Pearson et al. 1992). Fish also tightened schools and shifted their distribution downward. Normal position and behavior resumed 20 to 60 minutes after firing of the airgun ceased. A downward shift was also noted by Skalski et al. (1992) at received seismic sounds of 186 to 191 re: 1 μPa 0-to-peak. Caged European sea bass (*Dichentrarchus labrax*) showed elevated stress levels when exposed to airguns, but levels returned to normal after three days (Skalski 1992). These fish also showed a startle response when the seismic survey vessel was as much as 2.5 kilometer (1.3 nautical miles) away; this response increased in severity as the vessel approached and sound levels increased, but returned to normal after about two hours following cessation of airgun activity.

Whiting (*Merlangius merlangus*) exhibited a downward distributional shift upon exposure to 178 dB re: 1 μPa 0-to-peak sound from airguns, but habituated to the sound after one hour and returned to normal depth (sound environments of 185 to 192 dB re: 1 μPa) despite airgun activity (Chapman and Hawkins 1969). Whiting may also flee from sounds from airguns (Dalen and Knutsen 1986). Hake (*Merluccius* spp.) may re-distribute downward (La Bella et al. 1996). Lesser sand eels (*Ammodytes tobianus*) exhibited initial startle responses and upward vertical movements before fleeing from the seismic survey area upon approach of a vessel with an active source (Hassel et al. 2003; Hassel et al. 2004).

McCauley et al. (2000; 2000b) found small fish show startle responses at lower levels than larger fish in a variety of fish species and generally observed responses at received sound levels of 156 to 161 dB re: 1 μPa (rms), but responses tended to decrease over time suggesting habituation. As with previous studies, caged fish showed increases in swimming speeds and downward vertical shifts. Pollock (*Pollachius* spp.) did not respond to sounds from airguns received at 195 to 218 dB re: 1 μPa 0-to-peak, but did exhibit continual startle responses and fled from the acoustic source when visible (Wardle et al. 2001). Blue whiting (*Micromesistius poutassou*) and mesopelagic fishes were found to re-distribute 20 to 50 meters (65.6 to 164 feet) deeper in response to airgun ensonification and a shift away from the seismic survey area was also found (Slotte et al. 2004). Startle responses were infrequently observed from salmonids receiving 142 to 186 dB re: 1 μPa peak-to-peak sound levels from an airgun (Thomsen 2002). Cod (*Gadus* spp.) and haddock (*Melanogrammus aeglefinus*) likely vacate seismic survey areas in response to airgun activity and estimated catchability decreased starting at received sound levels of 160 to 180 dB re: 1 μPa 0-to-peak (Dalen and Knutsen 1986; Løkkeborg 1991; Engås et al. 1993; Løkkeborg and Soldal 1993b; Turnpenny et al. 1994; Engås et al. 1996b).

Increased swimming activity in response to airgun exposure on fish, as well as reduced foraging activity, is supported by data collected by Lokkeborg et al. (2012). Bass did not appear to vacate during a shallow-water seismic survey with received sound levels of 163 to 191 dB re: 1 μPa 0-to-peak (Turnpenny and Nedwell 1994). Similarly, European sea bass apparently did not leave their inshore habitat during a four- to five-month seismic survey (Pickett et al. 1994). La Bella et al. (1996) found no differences in trawl catch data before and after seismic survey activities and echosurveys of fish occurrence did not reveal differences in pelagic biomass. However, fish kept in cages did show behavioral responses to approaching operating airguns.

Squid are known to be important prey for sperm whales. Squid responses to operating airguns have also been studied, although to a lesser extent than fishes. In response to airgun exposure, squid exhibited both startle and avoidance responses at received sound levels of 174 dB re: 1 μPa (rms) by first ejecting ink and then moving rapidly away from the area (McCauley et al. 2000b; McCauley et al. 2000c; Fewtrell 2013b). The authors also noted some movement upward. During ramp-up, squid did not discharge ink but alarm responses occurred when received sound levels reached 156 to 161 dB re: 1 μPa (rms). Tenera Environmental (2011) reported that Norris and Mohl (1983, summarized in Mariyasu et al. 2004) observed lethal effects in squid (*Loligo vulgaris*) at levels of 246 to 252 dB after three to 11 minutes. Andre et al. (2011) exposed four cephalopod species (*Loligo vulgaris*, *Sepia officinalis*, *Octopus vulgaris*, and *Ilex coindetii*) to two hours of continuous sound from 50 to 400 Hertz at 157 ±5 dB re: 1 μPa. They reported lesions to the sensory hair cells of the statocysts of the exposed animals that increased in severity with time, suggesting that cephalopods are particularly sensitive to low-frequency sound. The received sound pressure level was 157 ±5 dB re: 1 μPa, with peak levels at 175 dB re: 1 μPa. Guerra et al. (2004) suggested that giant squid mortalities were associated with seismic surveys based upon coincidence of carcasses with the seismic surveys in time and space, as well as pathological information from the carcasses. Another laboratory story observed abnormalities in larval scallops after exposure to low frequency noise in tanks (de Soto et al. 2013).

Lobsters did not exhibit delayed mortality, or apparent damage to mechanobalancing systems after up to eight months post-exposure to airguns fired at 202 or 227 dB peak-to-peak pressure (Christian 2013). However, feeding did increase in exposed individuals (Christian 2013). Sperm whales regularly feed on squid and some fishes, and we expect individuals to feed while in the action area during the proposed seismic survey activities. Based upon the best available information, fishes and squids located within the sound fields corresponding to the approximate 160 dB re: 1 μPa (rms) isopleths could vacate the area and/or dive to greater depths.

The overall response of fishes and squids is to exhibit startle responses and undergo vertical and horizontal movements away from the sound field. We are not aware of any specific studies regarding sound effects on and the detection ability of other invertebrates such as krill (*Euphausiacea* spp.), the primary prey of most ESA-listed baleen whales. However, we do not expect krill to experience effects from sounds of airguns. Although humpback whales consume fish regularly, we expect that any disruption to their prey will be temporary, if at all. Therefore, we do not expect any adverse effects from a potential temporary lack of prey availability in localized areas to baleen whales. We expect indirect effects from airgun array operations through reduced feeding opportunities for ESA-listed marine mammals to be temporary and, if displaced, both marine mammals, sea turtles, and listed fish and their prey will re-distribute back into the action area once seismic survey activities have passed or concluded.

Based on the available data, we anticipate seismic survey activities will result in temporary and minor reduction in availability of prey for ESA-listed species near the airgun array immediately following the use of active seismic sound sources. This may be due to changes in prey distributions (i.e., due to avoidance) or abundance (i.e., due to mortality) or both. However, we do not expect this to have a meaningful impact on ESA-listed marine mammals, sea turtles, or fishes. As described above, we believe that, in most cases, ESA-listed marine mammals, sea turtles, and fishes will avoid closely approaching the airgun array when active, and as such will not be in areas from which prey have been temporarily displaced or otherwise affected.

10.3 Risk Analysis

In this section, we assess the consequences of the responses of the individuals that have been exposed, the populations those individuals represent, and the species those populations comprise.

We measure risks to individuals of threatened or endangered species based upon effects on the individual's fitness, which may be indicated by changes to the individual's growth, survival, annual reproductive fitness, and lifetime reproductive success. We expect the numbers of the following species to be exposed to the airgun array within 160 dB re: 1 μPa (rms) ensonified areas during the seismic survey activities:

- 40 blue,
- 94 fin,
- 42 Central DPS of humpback,
- 34 Mexico DPS of humpback,
- 30 sei,
- 72 sperm, and
- Southern Resident killer whales, and
- 2,048 Guadalupe fur seals

We expect up to three leatherback turtles to be exposed the airgun array within 175 dB re: 1 μPa (rms) ensonified areas during the seismic survey activities.

Expected exposures for ESA-listed Pacific salmon that would experience sound levels for TTS (187 dB) and injury (206 dB) are in Table 60, Table 61, and Table 62. We expect that 708,515 Southern DPS eulachon could be exposed at sound levels that could result in TTS, and of those, 39,179 could be exposed at sound levels that could result in injury. We were not able to calculate the number of individual Southern DPS green sturgeon.

Table 59. Estimated number of ESA-listed salmonids (hatchery fish w/adipose fin intact) that would experience TTS (187 dB) or be injured (206 dB) by seismic activities in the action area. Unless noted otherwise, - indicates there are no fish at this lifestage and ESU/DPS that would be affected by TTS or injury.

Species	Life stage	ESU/DPS	TTS	TTS Percentage	Injury	Injury Percentage
Chinook salmon	Adult	Sac River winter run - E	-	-	-	-
	Juvenile		-	-	-	-
	Adult	Central valley spring run - T	-	-	-	-
	Juvenile		-	-	-	-
	Adult	California coastal - T	-	-	-	-
	Juvenile		-	-	-	-
	Adult		879	2	56	0

Species	Life stage	ESU/DPS	TTS	TTS Percentage	Injury	Injury Percentage
	Juvenile	Snake River fall - T	61,886	2	3,965	0
	Adult	Snake River spring/summer - T	27	2	2	0
	Juvenile		16,762	2	1,074	0
	Adult[1]	Lower Columbia River - T	2,928	3	188	0
	Juvenile		19,090	3	1,560	0
	Adult[1]	Upper Willamette River - T	2,116	2	136	0
	Juvenile		4	2	-	-
	Adult	Upper Columbia River spring - E	218	2	14	0
	Juvenile		7,970	2	511	0
	Adult[1]	Puget Sound - T	2,744	6	176	0
	Juvenile		427,855	6	27,414	0
Coho salmon	Adult	Central California coast - E	186	28	12	2
	Juvenile		47,257	28	3,028	2
	Adult[1]	S. Oregon/N. California coast - T	1,712	8	110	1
	Juvenile		45,017	8	2,884	1
	Adult	Oregon coast - T	-	-	-	-
	Juvenile		-	-	-	-
	Adult	Lower Columbia River - T	2,351	13	151	1
	Juvenile		33,397	13	2,140	1
Chum salmon	Adult	Hood Canal summer run	14	0	1	0
	Juvenile		480	0	31	0
	Adult	Columbia River - T	4	0	-	-
	Juvenile		1,925	0	123	
Sockeye salmon	Adult	Ozette Lake - T	-	-	-	-
	Juvenile		-	-	-	-
	Adult	Snake River - E	-	-	-	-
	Juvenile		-	-	-	-
Steelhead	Adult	South-Central California - T	-	-	-	-
	Juvenile		-	-	-	-
	Adult		-	-	-	-

Species	Life stage	ESU/DPS	TTS	TTS Percentage	Injury	Injury Percentage
	Juvenile	Central California - T	-	-	-	-
	Adult	California Central Valley - T	-	-	-	-
	Juvenile		-	-	-	-
	Adult	Northern California - T	-	-	-	-
	Juvenile		-	-	-	-
	Adult	Upper Columbia River - E	4	0	-	-
	Juvenile		148	0	9	0
	Adult	Snake River basin - T	52	0	3	0
	Juvenile		752	0	48	0
	Adult[1]	Lower Columbia River - T	71	0	5	0
	Juvenile		10	0	1	0
	Adult	Upper Willamette River - T	-	-	-	-
	Juvenile		-	-	-	-
	Adult	Middle Columbia River - T	-	-	-	-
	Juvenile		118	0	8	0
	Adult	Puget Sound - T	-	-	-	-
	Juvenile		120	0	8	0

Table 60. Estimated number of ESA-listed salmonids (hatchery fish w/adipose fin clipped) that would experience TTS (187 dB) or be injured (206 dB) by seismic activities in the action area. Unless noted otherwise, - indicates there are no fish at this lifestage and ESU/DPS that would be affected by TTS or injury.

Species	Life stage	ESU/DPS	TTS	TTS Percentage	Injury	Injury Percentage
Chinook salmon	Adult	Sac River winter run - E	770	11	49	1
	Juvenile		22,985	11	1,473	1
	Adult	Central valley spring run - T	784	11	50	1
	Juvenile		249,307	11	15,974	1
	Adult	California coastal - T	-	-	-	-
	Juvenile		-	-	-	-
	Adult	Snake River fall - T	1,006	2	64	0
	Juvenile		53,698	2	3,441	0

Species	Life stage	ESU/DPS	TTS	TTS Percentage	Injury	Injury Percentage
	Adult	Snake River spring/summer - T	155	2	10	0
	Juvenile		96,289	2	6,170	0
	Adult[1]	Lower Columbia River - T	-	-	-	-
	Juvenile		792,955	3	50,808	0
	Adult[1]	Upper Willamette River - T	-	-	-	-
	Juvenile		105,547	2	6,763	0
	Adult	Upper Columbia River spring - E	404	2	26	0
	Juvenile		13,443	2	861	0
	Adult[1]	Puget Sound - T	-	-	-	-
	Juvenile		2,135,854	6	136,852	0
Coho salmon	Adult	Central California coast - E	-	-	-	-
	Juvenile		-	-	-	-
	Adult[1]	S. Oregon/N. California coast - T	-	-	-	-
	Juvenile		15,658	8	1,003	1
	Adult	Oregon coast - T	121	11	8	1
	Juvenile		6,477	11	415	1
	Adult	Lower Columbia River - T	-	-	-	-
	Juvenile		974,391	13	62,433	1
Chum salmon	Adult	Hood Canal summer run - T	-	-	-	-
	Juvenile		-	-	-	-
	Adult	Columbia River - T	-	-	-	-
	Juvenile		-	-	-	-
Sockeye salmon	Adult	Ozette Lake - T	38	0	2	0
	Juvenile		776	0	50	0
	Adult	Snake River - E	-	-	-	-
	Juvenile		-	-	-	-
Steelhead	Adult	South-Central California - T	-	-	-	-
	Juvenile		-	-	-	-
	Adult	Central California - T	12	0	1	0
	Juvenile		692	0	44	0

Species	Life stage	ESU/DPS	TTS	TTS Percentage	Injury	Injury Percentage
	Adult	California Central Valley - T	12	0	1	0
	Juvenile		1,706	0	109	0
	Adult	Northern California - T	-	-	-	-
	Juvenile		-	-	-	-
	Adult	Upper Columbia River - E	17	0	1	0
	Juvenile		733	0	47	0
	Adult	Snake River basin - T	254	0	16	0
	Juvenile		3,518	0	225	0
	Adult[1]	Lower Columbia River - T	-	-	-	-
	Juvenile		1,276	0	82	0
	Adult	Upper Willamette River - T	-	-	-	-
	Juvenile		-	-	-	-
	Adult	Middle Columbia River - T	1	0	-	-
	Juvenile		474	0	30	0
	Adult	Puget Sound - T	-	-	-	-
	Juvenile		117	0	8	0

Table 61. Estimated number of ESA-listed salmonids (natural fish) that would experience TTS (187 dB) or be injured (206 dB) by seismic activities in the action area. Unless noted otherwise, - indicates there are no fish at this lifestage and ESU/DPS that would be affected by mortality or injury.

Species	Life stage	ESU/DPS	TTS	TTS Percetage	Injury	Injury Percentage
Chinook salmon	Adult	Sac River winter run - E	72	11	5	1
	Juvenile		22,451	11	1,439	1
	Adult	Central valley spring run - T	1,285	11	82	1
	Juvenile		89,120	11	5,710	1
	Adult	California coastal - T	4,665	22	299	1
	Juvenile		282,538	22	18,103	1
	Adult	Snake River fall - T	670	2	43	0
	Juvenile		14,979	2	960	0
	Adult		830	2	53	0

Species	Life stage	ESU/DPS	TTS	TTS Percetage	Injury	Injury Percentage
	Juvenile	Snake River spring/summer - T	21,783	2	1,396	0
	Adult[1]	Lower Columbia River - T	2,236	3	143	0
	Juvenile		297,042	3	19,033	0
	Adult[1]	Upper Willamette River - T	686	2	44	0
	Juvenile		27,162	2	1,740	0
	Adult	Upper Columbia River spring - E	186	2	12	0
	Juvenile		10,136	2	649	0
	Adult[1]	Puget Sound - T	3,954	6	253	0
	Juvenile		178,605	6	11,444	0
Coho salmon	Adult	Central California coast - E	1,101	28	71	2
	Juvenile		45,049	28	2,886	2
	Adult[1]	S. Oregon/N. California coast - T	1,419	8	91	1
	Juvenile		157,644	8	10,101	1
	Adult	Oregon coast - T	20,365	11	1,305	1
	Juvenile		717,012	11	45,942	1
	Adult	Lower Columbia River - T	7,986	13	512	1
	Juvenile		88,441	13	5,667	1
Chum salmon	Adult	Hood Canal summer run - T	241	0	15	0
	Juvenile		12,449	0	798	0
	Adult	Columbia River - T	102	0	7	0
	Juvenile		21,206	0	1,359	0
Sockeye salmon	Adult	Ozette Lake - T	5	0	-	-
	Juvenile		61	0	4	0
	Adult	Snake River - E	2	0	-	-
	Juvenile		84	0	5	0
Steelhead	Adult	South-Central California - T	7	0	-	-
	Juvenile		265	0	5	0
	Adult	Central California - T	5	0	-	-
	Juvenile		672	0	17	0

Species	Life stage	ESU/DPS	TTS	TTS Percetage	Injury	Injury Percentage
	Adult	California Central Valley - T	23	0	1	0
	Juvenile		876	0	56	0
	Adult	Northern California - T	5	0	1	0
	Juvenile		672	0	43	0
	Adult	Upper Columbia River - E	23	0	1	0
	Juvenile		876	0	56	0
	Adult	Snake River basin - T	6	0	-	-
	Juvenile		213	0	14	0
	Adult[1]	Lower Columbia River - T	34	0	2	0
	Juvenile		851	0	55	0
	Adult	Upper Willamette River - T	41	0	3	-
	Juvenile		375	0	24	0
	Adult	Middle Columbia River - T	9	0	3	0
	Juvenile		150	0	24	0
	Adult	Puget Sound - T	16	0	1	0
	Juvenile		435	0	28	0

As described above, the proposed action will result in temporary effects, largely behavioral but with some potential for TTS to the exposed marine mammals and sea turtles (blue, fin, Central America DPS and Mexico DPS of humpback, sei, sperm, Southern Resident killer whales, Guadalupe fur seals, and leatherback turtles). Similarly, we expect that the proposed action will result in temporary behavioral effects with limited potential for TTS or injurious effects to exposed ESA-listed Chinook, Coho, chum, sockeye, steelhead, Southern DPS green sturgeon, or Southern DPS eulachon. The potential for adverse effects to result in injury or mortality is low in part due to the required mitigation measures (e.g., shutdown procedures) in the proposed IHA for the proposed seismic survey activities to protect ESA-listed species. As such, we believe the fitness consequences to ESA-listed marine mammals, sea turtles, or fishes exposed to the sound sources from the seismic survey will have a minimal effect on the populations of these species.

11 Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 C.F.R. §402.02). Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

We expect that those aspects described in the *Environmental Baseline* (Section 9) will continue to impact ESA-listed resources into the foreseeable future. We expect climate change, oceanic temperature regimes, vessel strikes, whale watching, fisheries (fisheries interactions and aquaculture), pollution (marine debris, pesticides and contaminants, and hydrocarbons), aquatic nuisance species, anthropogenic sound (vessel sound and commercial shipping, aircraft, seismic surveys, and marine construction), military activities, and scientific research activities to continue into the future with continuing impacts to marine mammals, sea turtles, and fishes. Because of recent trends and based on available information, we expect the amount and frequency of vessel activity to persist in the action area, and that ESA-listed species will continue to be impacted. Different aspects of vessel activity can impact ESA-listed species, such as vessel noise, disturbance, and the risk of vessel strike causing injury or mortality to marine mammals, especially large whales, and to a lesser extent, sea turtles and fishes. However, movement towards bycatch reduction and greater foreign protections of sea turtles are generally occurring throughout the Northeast Pacific Ocean, which may aid in abating the downward trajectory of sea turtle populations due to activities such as fishing in the action area. Similar legislative efforts for the conservation of Pacific salmon may also aid in improving the status of those populations in the action area; see discussion below.

During this consultation, we searched for information on future state, tribal, local, or private (non-Federal) actions that were reasonably certain to occur in the action area. We conducted electronic searches of *Google* and other electronic search engines for other potential future state or private activities that are likely to occur in the action area.

Future tribal, state, and local government actions will likely be in the form of legislation, administrative rules, or policy initiatives and fishing permits. Activities occurring in the action area are primarily those conducted under state and tribal management. These actions may include changes in ocean policy and increases and decreases in the types of activities currently seen in the action area, including changes in the types of fishing activities, resource extraction, and designation of marine protected areas, any of which could influence the status of listed species in the action area in the future. Government actions are subject to political, legislative and fiscal uncertainties. As a result, any analysis of cumulative effects is difficult, particularly when taking into account the geographic scope of the action area, the various authorities involved in the action, and the changing economies of the region.

An example of one such initiative is the Southern Resident Killer Whale Task Force, established through an executive order by the governor of Washington State to identify, prioritize, and support the implementation of a longer-term action plan for Southern Resident killer whale recovery. The Task Force provided recommendations in a final report in November 2018. Although it is likely that several of the recommended actions will occur, it is currently uncertain which ones will be implemented. In response to recommendations of the Task Force, the

Washington State Legislature provided approximately $13 million in funding "prioritized to increase prey abundance for southern resident orcas" (Engrossed Substitute House Bill 1109) for the 2019-2021 biennium (July 2019 through June 2021). The planned 2020 production associated with this legislative action is a release of an additional 13.5 million Chinook salmon (approximately 6.4 million from Puget Sound facilities, approximately 5.6 million from Washington coastal facilities, and approximately 1.5 million from Columbia River facilities). A similar level of Chinook salmon production funded by this legislative action is anticipated in the spring of 2021, meaning that the effects of hatchery releases on ESA-listed salmonids will continue and may increase in the future.

Washington State passed House Bill 1579 that addresses habitat protection of shorelines and waterways (Chapter 290, Laws of 2019 [2SHB 1579]), and funding was included for salmon habitat restoration programs and to increase technical assistance and enforcement of state water quality, water quantity, and habitat protection laws. Other state actions included measures to increase survival through the hydropower system on the Lower Snake and Lower Columbia Rivers, passed legislation to decrease impacts of predatory fish on salmon (Chapter 290, Laws of 2019 [2SHB 1579]), passed the federal Endangered Salmon Predation Prevention Act (PL 115-329) to provide state and tribal managers more flexibility to manage sea lion predation on the Columbia River, and provided funding to the Washington State Department of Transportation to complete fish barrier corrections and to implement a Lower Snake River dams stakeholder engagement process.

12 Integration and Synthesis

The *Integration and Synthesis* section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the *Effects of the Action* (Section 10) to the *Environmental Baseline* (Section 9) and the *Cumulative Effects* (Section 11) to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a ESA-listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat for the conservation of the species. These assessments are made in full consideration of the *Status of the Species and Critical Habitat* (Section 8).

Some ESA-listed species and designated critical habitat are located within the action area but are not expected to be affected by the action, or the effects of the action on these ESA resources were determined to be insignificant or discountable. Some activities evaluated individually were determined to have insignificant or discountable effects and thus to be not likely to adversely affect some ESA-listed species and designated critical habitats (Section 7).

The following discussions separately summarize the probable risks the proposed action poses to threatened and endangered marine mammals, leatherback sea turtles, and ESA-listed fish. These summaries integrate the exposure profiles presented previously with the results of our response analyses for each of the activities considered further in this opinion; specifically seismic survey activities and associated equipment sound levels.

12.1 Jeopardy Analysis

The jeopardy analysis relies upon the regulatory definition of "to jeopardize the continued existence of a listed species," which is "to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 C.F.R. §402.02). Therefore, the jeopardy analysis considers both the survival and recovery of the species.

Based on our effects analysis, adverse effects to ESA-listed species are likely to result from the action. The following discussions summarize the probable risks that seismic survey activities pose to ESA-listed species that are likely to be exposed over the approximately 37 days of the seismic survey activities. These summaries integrate our exposure, response, and risk analyses from Section 10.

12.1.1 Blue Whale

Adult and juvenile blue whales are present in the action area and are expected to be exposed to noise from the seismic survey activities. The severity of an animal's response to noise associated with the seismic survey will depend on the duration and severity of exposure.

The minimum population size for Eastern North Pacific Ocean blue whales is 1,050; the more recent abundance estimate is 1,496 whales (Carretta et al. 2020). Current estimates indicate a growth rate of just under three percent per year (Calambokidis et al. 2009). We expect that adults and juveniles may be affected by take in the form of PTS, TTS, or behavioral changes from sound sources associated with the seismic survey. Take may have short- or long-term consequences, depending on the level of noise from detonations to which animals are exposed. The anticipated take of animals is not expected to result in the loss of reproduction at an individual level or to have a measurable effect on reproduction at the population level.

No reduction in the distribution of blue whales from the Pacific Ocean or changes to the geographic range of the species are expected because of the National Science Foundation and L-DEO's seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization.

No reduction in numbers is anticipated due to the proposed actions. Therefore, no reduction in reproduction is expected as a result of the proposed actions. Non-lethal take of 59 individuals, adults and juveniles, is expected as a result of the proposed seismic survey activities. We anticipate temporary behavioral responses, with individuals returning to normal shortly after the exposure has ended, and thus do not anticipate any delay in reproduction as a result. Because we do not anticipate a reduction in numbers or reproduction of blue whales as a result of the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization, a reduction in the species' likelihood of survival is not expected.

The Final Recovery Plan for the blue whale lists recovery objectives for the species. The following recovery objectives are relevant to the impacts of the proposed actions:

- Reduce or eliminate human-caused injury and mortality of blue whales.
- Minimize detrimental effects of directed vessel interactions with blue whales.
- Coordinate state, federal, and international efforts to implement recovery actions for blue whales.

Because no mortalities or effects on the abundance, distribution, and reproduction of blue whale populations are expected as a result of the proposed actions, we do not anticipate the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization will impede the recovery objectives for blue whales. In conclusion, we believe the non-lethal effects of take associated with the proposed actions will not jeopardize the continued existence of blue whales.

12.1.2 Fin Whale

Adult and juvenile fin whales are present in the action area and are expected to be exposed to noise from the seismic survey activities. The severity of the individual's response to noise associated with the seismic survey will depend on the duration and severity of the exposure.

Current estimates indicate approximately 10,000 fin whales in U.S. Pacific Ocean waters, with an annual growth rate of 4.8 percent in the Northeast Pacific and a stable population abundance in the California/Oregon/Washington stock (Nadeem et al. 2016).

We expect that adults and juveniles may be affected by take in the form of PTS, TTS, or behavioral changes from sound sources associated with the seismic survey. We anticipate temporary behavioral responses, with individuals returning to normal shortly after the exposure has ended. No reduction in the distribution of fin whales from the Pacific Ocean is expected because of the National Science Foundation and L-DEO's seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization. No reduction in numbers is anticipated due to the proposed actions. Therefore, no reduction in reproduction is expected because of the proposed actions. There are expected to be one individual harmed and 96 individuals, adults and juveniles, harassed because of the proposed seismic survey activities. Because we do not anticipate a reduction in numbers, distribution, or reproduction of fin whales as a result of the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization, a reduction in the species' likelihood of survival is not expected.

The 2010 Final Recovery Plan for the fin whale lists recovery objectives for the species. The following recovery objectives are relevant to the impacts of the proposed actions:

- Achieve sufficient and viable population in all ocean basins.

- Ensure significant threats are addressed.

Because no mortalities or effects on the distribution of fin whale populations are expected as a result of the proposed actions, we do not anticipate the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization will impede the recovery objectives for fin whales. In conclusion, we believe the effects associated with the proposed actions are not expected to cause a reduction in the likelihood of survival and recovery of fin whales in the wild.

12.1.3 Sei Whale

Adult and juvenile sei whales are present in the action area and are expected to be exposed to noise from the seismic survey activities. The severity of an individual's response to noise associated with the seismic survey will depend on the duration and severity of exposure.

Models indicate that total abundance declined from 42,000 to 8,600 individuals between 1963 and 1974 in the North Pacific Ocean. More recently, the North Pacific Ocean population was estimated to be 29,632 (95 percent confidence intervals 18,576 to 47,267) between 2010 and 2012 (IWC 2016; Thomas et al. 2016). Population growth rates for sei whales are not available at this time as there are little to no systematic survey efforts to study sei whales.

We expect that adults and juveniles may be affected by take in the form of PTS, TTS, or behavioral changes from sound sources associated with the seismic survey. There are expected to be two individuals harmed and 31 individuals, adults and juveniles, harassed because of the proposed seismic survey activities. No reduction in the distribution of sei whales from the Pacific Ocean is expected because of the National Science Foundation and L-DEO's seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization. No reduction in numbers is anticipated due to the proposed actions. Therefore, no reduction in reproduction is expected because of the proposed actions. Because we do not anticipate a reduction in numbers or reproduction of sei whales as a result of the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization, a reduction in the species' likelihood of survival is not expected.

The 2001 Final Recovery Plan for the sei whale lists recovery objectives for the species. The following recovery objectives are relevant to the impacts of the proposed actions:

- Achieve sufficient and viable populations in all ocean basins.
- Ensure significant threats are addressed.

Because no mortalities or effects on the distribution of sei whales are expected as a result of the proposed actions, we do not anticipate the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization will impede the recovery objectives for sei whales. In conclusion, we believe the effects associated with the proposed actions are not expected to cause a reduction in the likelihood of survival and recovery of sei whales in the wild.

12.1.4 Humpback Whale—Central America DPS

Adult and juvenile Central America DPS humpback whales are present in the action area and are expected to be exposed to noise from the seismic survey activities.

The global, pre-exploitation estimate for humpback whales is 1,000,000 (Roman and Palumbi 2003). The current abundance of the Central America DPS is 411. A population growth rate is currently unavailable for the Central America DPS of humpback whales.

We expect that adults and juveniles may be affected by take in the form of PTS, TTS, or behavioral changes from sound sources associated with the seismic survey. The severity of an animal's response to noise associated with the seismic survey will depend on the duration and severity of exposure. No reduction in the distribution of Central America DPS of humpback whales from the Pacific Ocean is expected because of the National Science Foundation and L-DEO's seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization.

No reduction in numbers is anticipated due to the proposed actions. Therefore, no reduction in reproduction is expected because of the proposed actions. There are expected to be 11 individuals harmed and 42 individuals harassed, adults and juveniles, because of the proposed seismic surveys. Because we do not anticipate a reduction in numbers or reproduction of Central DPS of humpback whales as a result of the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization, a reduction in the species' likelihood of survival is not expected.

The 1991 Final Recovery Plan for the humpback whale lists recovery objectives for the species. The following recovery objectives are relevant to the impacts of the proposed actions:

- Maintain and enhance habitats used by humpback whales currently or historically.
- Identify and reduce direct human-related injury and morality.
- Measure and monitor key population parameters.
- Improve administration and coordination of recovery program for humpback whales.

Because no mortalities or effects on the distribution of Central America DPS of humpback whales are expected as a result of the proposed actions, we do not anticipate the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization will impede the recovery objectives for Central America DPS of humpback whales. In conclusion, we believe the effects associated with the proposed actions are not expected to cause a reduction in the likelihood of survival and recovery of Central America of DPS of humpback whales in the wild.

12.1.5 Humpback Whale—Mexico DPS

Adult and juvenile Mexico DPS humpback whales are present in the action area and are expected to be exposed to noise from the seismic survey activities.

The global, pre-exploitation estimate for humpback whales is 1,000,000 (Roman and Palumbi 2003). The current abundance of the Mexico DPS is unavailable. A population growth rate is currently unavailable for the Mexico DPS of humpback whales.

There are expected to be nine individuals harmed and 34 individuals, juveniles and adults, harassed because of the proposed seismic survey activities. No reduction in the distribution of Mexico DPS of humpback whales from the Pacific Ocean is expected because of the National Science Foundation and L-DEO's research activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization.

No reduction in numbers is anticipated due to the proposed actions. Therefore, no reduction in reproduction is expected because of the proposed actions. Because we do not anticipate a reduction in numbers or reproduction of Mexico DPS of humpback whales as a result of the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization, a reduction in the species' likelihood of survival is not expected.

The 1991 Final Recovery Plan for the humpback whale lists recovery objectives for the species. The following recovery objectives are relevant to the impacts of the proposed actions:

- Maintain and enhance habitats used by humpback whales currently or historically.
- Identify and reduce direct human-related injury and morality.
- Measure and monitor key population parameters.
- Improve administration and coordination of recovery program for humpback whales.

Because no mortalities or effects on the distribution of Mexico DPS of humpback whales are expected as a result of the proposed actions, we do not anticipate the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization will impede the recovery objectives for Mexico DPS of humpback whales. In conclusion, we believe the effects associated with the proposed actions are not expected to cause a reduction in the likelihood of survival and recovery of Mexico DPS of humpback whales in the wild.

12.1.6 Sperm Whale

Adult and juvenile sperm whales are present in the action area and are expected to be exposed to noise from the seismic survey activities.

The sperm whale is the most abundant of the large whale species, with total abundance estimates between 200,000 and 1,500,000. The most recent estimate indicated a global population of between 300,000 and 450,000 individuals (Whitehead 2009). The higher estimates may be approaching population sizes prior to commercial whaling. In the Northeast Pacific Ocean, the abundance of sperm whales was estimated to be between 26,300 and 32,100 in 1997. In the northeast Pacific Ocean, the abundance of sperm whales was estimated to be between 26,300 and 32,100 in 1997. There is insufficient data to evaluate trends in abundance and growth rates of sperm whales at this time.

There are expected to be zero individuals harmed and 73 individuals, adults and juveniles, harassed because of the proposed seismic survey activities. No reduction in the distribution of sperm whales from the Pacific Ocean is expected because of the National Science Foundation and L-DEO's seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization. No reduction in numbers is anticipated as part of the proposed actions. Therefore, no reduction in reproduction is expected due to the proposed actions. Because we do not anticipate a reduction in numbers or reproduction of sperm whales as a result of the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization, a reduction in the species' likelihood of survival is not expected.

The 2010 Final Recovery Plan for the sperm whale lists recovery objectives for the species. The following recovery objectives are relevant to the impacts of the proposed actions:

- Achieve sufficient and viable populations in all ocean basins.
- Ensure significant threats are addressed.

Because no mortalities or effects on the distribution of sperm whales are expected as a result of the proposed actions, we do not anticipate the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization will impede the recovery objectives for sperm whales. In conclusion, we believe the effects associated with the proposed actions are not expected to cause a reduction in the likelihood of survival and recovery of sperm whales in the wild.

12.1.7 Southern Resident Killer Whale

The Southern Resident killer whale DPS was listed as endangered under the ESA on November 18, 2005. The cumulative and synergistic effects of multiple threats have resulted in the continued decline of the Southern Resident killer whale population. Between 1967 and 1973, about 30 percent of the population was captured live for displays in oceanaria. The primary ongoing threats to the recovery of this population include quantity and quality of prey, toxic chemicals that accumulate in top predators, and disturbance from sound and vessels. Based on their population size and life history traits (i.e., slow-growing mammals that give birth to single calves with several years between births), we assume that Southern Resident killer whales would have elevated extinction probabilities due to a combination of exogenous anthropogenic threats (as discussed above in the Section 8.4.4 *Status of the Species* and Section 9 *Environmental Baseline*), natural phenomena (including vulnerability to disease), and endogenous threats resulting from their small population size.

A growing body of evidence documents how Southern Resident killer whales are affected by prey limitations, particularly Chinook salmon. Salmon populations in the Pacific Northwest have declined due to a combination of factors including land alteration associated with agriculture and timber harvest practices, the construction of dams, urbanization, fishery harvest practices, hatchery operations, and increased predation from a growing population of pinnipeds. When prey is scarce, whales likely spend more time foraging than when it is plentiful. Increased energy expenditure and prey limitation can cause nutritional stress. Nutritional stress is the condition of being unable to acquire adequate energy and nutrients from prey resources and as a chronic condition can lead to reduced body size and condition of individuals and lower birth and survival rates in a population. Indicators of nutritional stress include the poor condition individual Southern Resident killer whales are occasionally found in, and variable levels of the thyroid hormone triiodothyronine (Wasser et al. 2017). In addition, Southern Resident killer whale fecundity, death rates and rates of population increase have shown statistical correlations with some indices of Chinook salmon abundance (Hilborn et al. 2012).

Vessel traffic exposes Southern Resident killer whales to several threats that have consequences for the species' likelihood of survival and recovery. Three vessels strikes, two lethal and one sublethal, of Southern Resident killer whales have been documented in the past 15 years. In addition to strikes, the number and proximity of vessels, particularly whale-watch vessels in the inland areas occupied by Southern Resident killer whales, represents a source of chronic disturbance and stress for this population. With the disruption of feeding behavior that has been observed, it is estimated that the presence of vessels could result in an 18 percent decrease in energy intake, a consequence that could have a significant negative effect on an already prey-limited species (Williams et al. 2006a; Lusseau et al. 2009b). Foraging behavior may also be impacted by sound that interferes with the whales' echolocation from vessels or other sounds sources. In addition to the disturbance associated with the presence of vessels, vessel traffic affects the acoustic landscape that may affect Southern Resident killer whale communication and social ecology. Vessels in the path of the whales can interfere with important social behaviors such as prey sharing (Ford and Ellis 2006) or nursing (Kriete 2007).

Exposure to contaminants may also harm Southern Resident killer whales. Because of their long life span, position at the top of the food chain, and their blubber stores, killer whales are capable of accumulating high concentrations of contaminants. The presence of high levels of persistent organic pollutants, such as PCB, DDT, and flame-retardants has been documented in Southern Resident killer whales (Ross et al. 2000; Krahn et al. 2007b). Although the consequences of these pollutants on the fitness of individual killer whales and the population as a whole remain unknown, in other species these pollutants have been reported to suppress immune responses (Wright et al. 2007), impair reproduction, and exacerbate the energetic consequences of physiological stress responses when they interact with other compounds in an animal's tissues (Martineau 2007).

In the mid- to late-1800s, the Southern Resident killer whale DPS was estimated to have numbered around 200 individuals. For the period between 1974 and the mid-1990s, when the population increased from 76 to 93 animals, the population growth rate was 1.8 percent. A delisting criterion for the Southern Resident killer whale DPS is an average growth rate of 2.3 percent for 28 years (NMFS 2008d). More recent data indicate the population is now in decline (Carretta 2019b). The current population estimate of 74 represents a decline from the recent past, when in 2012 there were 85 whales. As compared to stable or growing populations, the DPS reflects lower fecundity and has demonstrated little to no growth in recent decades (NMFS 2016h).

Given the low current population size, Southern Resident killer whales likely have a higher probability of becoming extinct because of demographic stochasticity, demographic heterogeneity (Coulson et al. 2006; Fox 2007), including stochastic sex determination (Lande et al. 2003), and the effects of phenomena interacting with environmental variability. The very small estimated effective population size (about 26 individuals), the absence of gene flow from other populations, and documented breeding within pods may elevate the risk from inbreeding and other issues associated with genetic deterioration (Ford et al. 2018b). These phenomena would likely amplify the potential consequences of anthropogenic stressors on this species.

The proposed action is expected to expose 11 Southern Resident killer whales, adults and juveniles, to behavioral harassment over the 37 days of seismic activities. No exposures resulting in PTS of Southern Resident killer whales were predicted (see 10.2.1.2 for details).

Southall et al. (2016) suggested that even minor, sub-lethal behavioral changes may still have significant energetic and physiological consequences given sustained or repeated exposure. The consequences of exposure to the anticipated acoustics effects would be more significant for whales that are already in poor condition; as such, animals would be less likely to compensate for additional energy expenditures or lost foraging or reproductive opportunities. Southern Resident killer whale individuals are occasionally found in poor condition, which may indicate nutritional stress. However, sustained or repeated disturbance is unlikely for any individual Southern Resident killer whale given the relatively low estimated number of exposures predicted. The proposed action would not take place in the areas of the Washington and Vancouver Island coasts where we expect the highest density of Southern Resident killer whales (see Figure 44; (Navy 2019)). Seismic activities would occur further off the coast than where we expect Southern Resident killer whales to spend the majority of their time in waters less than 100 meters deep, and within 34 kilometers of shore (NMFS 2019c).

Exposures would likely be short-term. The seismic activities in the proposed action will last 37 days, with seismic activities nearest the Washington and Vancouver Island coasts lasting a few days at most. Based on the available literature that indicates such infrequent exposures are unlikely to impact an individual's overall energy budget (Southall et al. 2007a; New et al. 2014; King et al. 2015; Villegas-Amtmann et al. 2015; Harris et al. 2017; NAS 2017; Farmer et al.

2018). We do not expect this level of exposure to impact the fitness of exposed Southern Resident killer whales, even individuals that are already in poor condition.

The injury, TTS, and behavioral effects for salmonids that would result from the stressors associated with the airgun array could have indirect effects on Southern Resident killer whales by reducing prey availability. We do not expect any mortality of fish because of the proposed action. A reduction in the availability of their prey may cause killer whales to forage for longer periods, travel to alternate locations, or abandon foraging efforts. Limitations in their prey availability is considered one of the primary threats affecting the survival and recovery of Southern Resident killer whales. Our analysis of the effects of the proposed action on Southern Resident killer whales via impacts to their prey focused on Chinook salmon, their primary prey throughout their range (Ford et al. 2010; Hanson et al. 2010a; Hilborn et al. 2012; Ford et al. 2016; NMFS 2019a; Hanson In prep), as well as Coho and chum salmon, which may be important as substitute species when the availability of Chinook salmon is reduced (Ford et al. 2016).

Based on our quantitative analysis, the estimated annual number of Chinook, Coho, and chum exposed to injury and TTS during the proposed seismic activities represents an extremely small fraction of the total number of salmon in those populations. As discussed previously, our fish effects analysis is based on a number of conservative assumptions that likely result in conservatively high estimates of salmonid fish injury and TTS from seismic activities. Behavioral effects that may cause displacement of ESA-listed Pacific salmonids are expected to last for a few days (Skalski et al. 1992; Slotte et al. 2004). While a displacement of prey may cause Southern Resident killer whales to expend more time and energy to search for prey, we do not consider these effects to last for such a duration that would result in fitness consequences for the Southern Resident killer whales. As described earlier, the proposed action would take place away from the areas with the highest expected Southern Resident killer whales densities. Southern Resident killer whales are presumably in those areas for foraging, and excluding those areas from the proposed seismic activities would reduce the effects to prey species there as well. Based on our effects analysis and considering the proposed mitigation measures, we do not expect these changes in prey distribution to persist or be so large that they result in more than a minor change to the overall health of any individual whale, or that they change the status of the population. Thus, even assuming a measurable effect, this would not rise to the level of an appreciable reduction in the likelihood of survival of any individual whale or the population as a whole.

The Recovery Plan for Southern Resident killer whales includes recovery goals concerning ensuring prey availability, reducing pollution and contamination, reducing the effects of vessels, preventing oil spills, minimizing the effects of anthropogenic sound, promoting education and outreach, improving response for sick, stranded, or injured killer whales, improving transboundary and interagency coordination for conservation efforts, and conducting research and monitoring to enhance conservation.

Because no mortalities or effects on the distribution of Southern Resident killer whales are expected as a result of the proposed actions, we do not anticipate the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization will impede the recovery objectives for Southern Resident killer whales. In conclusion, we believe the effects associated with the proposed actions are not expected to cause a reduction in the likelihood of survival and recovery of Southern Resident killer whales in the wild.

12.1.8 Guadalupe Fur Seal

Adult Guadalupe fur seals are present in the action area and are expected to be exposed to noise from the seismic survey activities.

All Guadalupe fur seals represent a single population, with two known breeding colonies in Mexico, and a purported breeding colony in the United States. When the more recent NMFS stock assessment report for Guadalupe fur seals was published in 2000, the breeding colonies in Mexico were increasing; evidence that is more recent indicates that this trend is continuing (Aurioles-Gamboa et al. 2010; Esperon-Rodriguez and Gallo-Reynoso 2012). After compiling data from counts over 30 years, Gallo calculated that the population of Guadalupe fur seals in Mexico was increasing, with an average annual growth rate of 13.3 percent on Guadalupe Island (Gallo-Reynoso 1994). More recent estimates of the Guadalupe fur seal population of the San Benito Archipelago (from 1997 through 2007) indicates that it is increasing as well at an annual rate of 21.6 percent (Esperon-Rodriguez and Gallo-Reynoso 2012), and that this population is at a phase of exponential increase (Aurioles-Gamboa et al. 2010). The most recent NMFS stock assessment report states that Guadalupe fur seals are increasing at an average rate of 10.3 percent. Direct counts of animals at Isla Guadalupe and Isla San Benito during 2010 resulted in a minimum of 13,327 animals and 2,503 animals respectively, for a minimum population size of 15,380 animals (Carretta et al. 2017).

No reduction in the distribution of Guadalupe fur seals from the Pacific Ocean is expected because of the National Science Foundation and L-DEO's seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization.

No reduction in numbers is anticipated due to the proposed actions. There are expected to be zero individuals harmed and 2,161 adults harassed because of the proposed seismic survey activities. Therefore, no reduction in reproduction is expected because of the proposed actions. Because we do not anticipate a reduction in numbers or reproduction of Guadalupe fur seals as a result of the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization, a reduction in the species' likelihood of survival is not expected.

There has been no Recovery Plan prepared for Guadalupe fur seals.

Because no mortalities or effects on the distribution of Guadalupe fur seals are expected as a result of the proposed actions, we do not anticipate the proposed seismic survey activities and the

NMFS Permits and Conservation Division's issuance of an incidental harassment authorization will impede the recovery objectives for Guadalupe fur seals. In conclusion, we believe the effects associated with the proposed actions are not expected to cause a reduction in the likelihood of survival and recovery of Guadalupe fur seals in the wild.

12.1.9 Leatherback Sea Turtle

Adult leatherback sea turtles are present in the action area and are expected to be exposed to noise from the seismic survey activities.

Leatherback turtle populations in the Pacific Ocean are low. Overall populations in the Pacific Ocean have declined from an estimated 81,000 individuals to less than 3,000 total adults and subadults (Spotila et al. 2000). Counts of leatherback turtles at nesting beaches in the western Pacific Ocean indicate that the subpopulation has been declining at a rate of almost six percent per year since 1984 (Tapilatu et al. 2013).

No reduction in the distribution of leatherback turtles from the Pacific Ocean is expected because of the National Science Foundation and L-DEO's seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization.

No reduction in numbers is anticipated due to the proposed actions. There are expected to be zero individuals harmed and three adults harassed because of the proposed seismic survey activities. Therefore, no reduction in reproduction is expected because of the proposed actions. Because we do not anticipate a reduction in the numbers or reproduction of leatherback turtles as a result of the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization, a reduction in the species' likelihood of survival is not expected.

The Pacific Recovery Plan for the population of leatherback turtles lists recovery objectives for the species. The following recovery objective is relevant to the impacts of the proposed action:

- Monitoring and research.

Because no mortalities or effects on the distribution of leatherback turtle populations are expected as a result of the proposed actions, we do not anticipate the proposed seismic survey activities and the NMFS Permits and Conservation Division's issuance of an incidental harassment authorization will impede the recovery objectives for leatherback turtles. In conclusion, we believe the effects associated with the proposed actions are not expected to cause a reduction in the likelihood of survival and recovery of leatherback turtles in the wild.

12.1.10 Chinook Salmon

Within the action area, nine ESUs of Chinook salmon may be exposed to sounds associated with the National Science Foundation's proposed seismic activities. These include the endangered Sacramento River winter-run and Upper Columbia River spring-run ESUs, and threatened California coastal, Central Valley spring-run, Lower Columbia River, Puget Sound, Snake River fall-run, Snake River spring/summer-run, and Upper Willamette River ESUs. Individuals exposed will be in the marine environment, and will be subadults or adults.

Listing dates for each of these Chinook salmon ESUs are provided in Table 5. Primary threats to Chinook salmon include blocked access to spawning grounds, habitat degradation caused by dams and culverts, and commercial fishing. Further, impacts from recent draughts have also caused the species population numbers to decrease.

Any Chinook salmon located within the ensonified area of the airgun array could be injured, sustain some degree of TTS or exhibit behavioral disruptions. Severity of injury would likely increase closer to the array, where impacts are more probable within a close distance.

The maximum annual total number of estimated injuries and TTS along with the proportion of Chinook salmon experiencing those effects from all nine ESUs likely to be adversely affected by seismic activities are presented in Table 60, Table 61, and Table 62.

Further, the ranges to effects used in our effects analysis are based on a zone of impact that would encompass the distance it would take for the sound wave to reach the criteria for the most sensitive fish species and life stages. This is likely a conservative approach for adult and subadult Chinook salmon which, given their large size, would likely be less sensitive to the effects of explosives than the smaller species and life stages these criteria were based on. If injured, large adult and subadult Chinook would also likely recover faster from sublethal injuries, as compared to juveniles, with a lower likelihood of fitness consequences or long-term effects on their survival or future reproductive potential.

Overall, the level of injury represents a reduction in abundance that may impact the future reproductive potential of Chinook populations but is not likely to appreciably reduce the likelihood of survival and recovery of any ESA-listed Chinook salmon ESU.

Some individual Chinook salmon may experience TTS because of the action's impulsive acoustic stressors. However, Chinook salmon lack notable hearing specialization, minimizing the likelihood of each instance of TTS affecting an individual's fitness. These species are able to rely on alternative mechanisms (e.g., sight, lateral line system) to detect prey, avoid predators, spawn, and to orient in the water column (Popper et al. 2014a). Additionally, hearing is not thought to play a role in Chinook salmon migration (e.g., Putnam et al. 2013). TTS is also short in duration with fish being able to replace hair cells when they are damaged (Lombarte et al. 1993; Smith et al. 2006). Because Chinook salmon are able to rely on alternative mechanisms for essential life functions, instances of TTS would not increase the likelihood of injury by annoying a fish to such an extent as to significantly disrupt normal behavioral patterns, including breeding, feeding, or sheltering and would not rise to the level of take.

Additionally, behavioral effects resulting from reactions to sound created by the airguns will be temporary (e.g., a startle response), and we do not expect these reactions to have any measurable effects on any individual's fitness. We expect individuals that exhibit a temporary behavioral response will return to pre-exposure behavior soon after the airgun array leaves the area. Similar to instances of TTS, we do not expect these short-term behavioral reactions to increase the likelihood of injury by annoying a fish to such an extent as to significantly disrupt normal behavioral patterns, including breeding, feeding, or sheltering and would not rise to the level of take.

Based on the evidence available, including the *Environmental Baseline, Effects of the Action* and *Cumulative Effects*, effects resulting from stressors caused by seismic activities, or cumulatively for the reasonably foreseeable future (assuming there are no significant changes to the *Status of Listed Resources* or *Environmental Baseline*), would not be expected to appreciably reduce the likelihood of the survival of ESA-listed Chinook salmon ESUs in the wild by reducing the reproduction, numbers, or distribution of the species or ESUs. We also conclude that effects from seismic activities continuing into the reasonably foreseeable future would not be expected, directly or indirectly, to appreciably reduce the likelihood of recovery of ESA-listed Chinook salmon ESUs in the wild by reducing the reproduction, numbers, or distribution of that species. Therefore, we do not anticipate any measurable or detectable reductions in survival rate or trajectory of recovery of the California coastal, Central Valley spring-run, Lower Columbia River, Puget Sound, Sacramento River winter-run, Snake River fall-run, Snake River spring/summer-run, Upper Columbia River spring-run, and Upper Willamette River ESUs of Chinook salmon.

12.1.11 Chum Salmon

Within the action area, two ESUs of ESA-listed chum salmon may be exposed to sound sources associated with the National Science Foundation's seismic activities. These include the threatened Columbia River ESU and Hood Canal summer-run ESU. Individuals exposed will be in the marine environment, and will be subadults or adults. Listing dates for each of these chum salmon ESUs are provided in Table 5. Major threats to chum salmon include blocked access to spawning grounds and habitat degradation caused by dams and culverts.

Any chum salmon located within the ensonified area of the airgun array could be injured, sustain some degree of TTS or exhibit behavioral disruptions. Severity of injury would likely increase closer to the array, where impacts are more probable within a close distance. As shown in Tables 60, 61, and 62, an extremely small percentage of each chum salmon ESU would be injured from the seismic activities. Due to their size, injured adult and subadult chum would also likely recover faster from sublethal injuries, as compared to juveniles, with a lower likelihood of fitness consequences or long-term effects on their survival or future reproductive potential.

Some individual chum salmon may experience TTS because of the seismic impulsive acoustic stressors. However, chum salmon lack notable hearing specialization, minimizing the likelihood of each instance of TTS affecting an individual's fitness. These species are able to rely on alternative mechanisms (e.g., sight, lateral line system) to detect prey, avoid predators, spawn, and to orient in the water column (Popper et al. 2014a). Additionally, hearing is not thought to play a role in chum salmon migration (e.g., Putnam et al. 2013). TTS is also short in duration with fish being able to replace hair cells when they are damaged (Lombarte et al. 1993; Smith et al. 2006). Because chum salmon are able to rely on alternative mechanisms for essential life functions, instances of TTS would not increase the likelihood of injury by annoying a fish to such an extent as to significantly disrupt normal behavioral patterns, including breeding, feeding, or sheltering and would not rise to the level of take.

Additionally, behavioral effects on chum salmon resulting from reactions to sound created by the airguns will be temporary (e.g., a startle response), and we do not expect these reactions to have any measurable effects on any individual's fitness. We expect individuals that exhibit a temporary behavioral response will return to pre-exposure behavior soon after the airgun array leaves the area. Similar to instances of TTS, we do not expect these short-term behavioral reactions to increase the likelihood of injury by annoying a fish to such an extent as to significantly disrupt normal behavioral patterns, including breeding, feeding, or sheltering and would not rise to the level of take.

A proportion of chum salmon from the Hood Canal summer-run ESU would likely be injured because of the seismic survey. Although we cannot quantify based on the available information, we expect that some proportion of chum salmon injuries from exposure to the seismic survey would likely result in fitness consequences, thus affecting the future survival and reproductive potential of the individual fish affected. As described in Section 9.3.1.5, the methodology used to quantify injury and mortality was based on several conservative assumptions which likely resulted in conservatively high estimates.

The two most recent status reviews (2011 and 2015) indicate some positive signs for the Hood Canal summer-run chum salmon ESU. Diversity has increased from the low levels seen in the 1990s due to both the reintroduction of spawning aggregates and the more uniform relative abundance between populations; considered a good sign for viability in terms of spatial structure and diversity (Ford 2011b). Spawning distribution within most streams was also extended further upstream with increased abundance. At present, spatial structure and diversity viability parameters for each population nearly meet the viability criteria (NWFSC 2015b). Spawning abundance has remained relatively high compared to the low levels observed in the early 1990's (Ford 2011b). Natural-origin spawner abundance has shown an increasing trend since 1999, and spawning abundance targets in both populations were met in some years (NWFSC 2015b). Thus, while some proportion of chum salmon injuries from seismic activity would likely result in fitness consequences, the level of impacts anticipated would not appreciably affect the population abundance or trend of the Hood Canal summer-run chum salmon ESU at the population level.

Based on the evidence available, including the *Environmental Baseline, Effects of the Action* and *Cumulative Effects*, effects resulting from stressors caused by the National Science Foundation's seismic survey, or cumulatively for the reasonably foreseeable future (assuming there are no significant changes to the *Status of Listed Resources* or *Environmental Baseline*), would not be expected to appreciably reduce the likelihood of the survival of either the Hood Canal summer-run ESU or Columbia River ESU of chum salmon in the wild by reducing the reproduction, numbers, or distribution of the species or ESUs. Therefore, we do not anticipate any measurable or detectable reductions in survival rate or trajectory of recovery of the Hood Canal summer-run ESU or Columbia River ESU of chum salmon.

12.1.12 Coho

Within the action area, four ESUs of Coho salmon may be exposed to sound associated with the National Science Foundation's seismic survey. These include the endangered Central California coast ESU and the threatened Lower Columbia River ESU, Oregon coast ESU, and Southern Oregon and Northern California coast ESU. Individuals exposed will be in the marine environment, and will be subadults or adults.

Listing dates for each of the Coho salmon ESUs are listed in Table 5. The main threats to Coho salmon include blocked access to spawning grounds and habitat degradation caused by dams and culverts.

Any Coho salmon located within the ensonified area of the airgun array could be injured, sustain some degree of TTS or exhibit behavioral disruptions. Severity of injury would likely increase closer to the array, where impacts are more probable within a close distance.

As shown in Tables 60, 61, and 62, only a small annual percentage of each Coho salmon ESU may be injured or experience TTS by the National Science Foundation's seismic activities. If injured, large adult and subadult Coho would also likely recover faster from sublethal injuries, as compared to juveniles, with a lower likelihood of fitness consequences or long-term effects on their survival or future reproductive potential.

This level of TTS and injury anticipated represents a very small reduction in abundance that is not likely to appreciably reduce the likelihood of survival and recovery of any ESA-listed Coho salmon ESU. Additionally, we conclude that the diversity of ESA-listed Coho salmon ESUs will not be affected by this limited amount of mortality or injury because it is expected to be distributed across populations through the species' ranges in the ocean. As a result, the seismic activities proposed by the National Science Foundation would not appreciably reduce the likelihood of ESA-listed Coho salmon surviving and recovering in the wild.

Some individual Coho salmon may experience TTS because of the seismic airgun impulsive acoustic stressors. However, Coho salmon lack notable hearing specialization, minimizing the likelihood of each instance of TTS affecting an individual's fitness. These species are able to rely on alternative mechanisms (e.g., sight, lateral line system) to detect prey, avoid predators, spawn, and to orient in the water column (Popper et al. 2014a). Additionally, hearing is not thought to play a role in Coho salmon migration (e.g., Putnam et al. 2013). TTS is also short in duration with fish being able to replace hair cells when they are damaged (Lombarte et al. 1993; Smith et al. 2006). Because Coho salmon are able to rely on alternative mechanisms for essential life functions, instances of TTS would not increase the likelihood of injury by annoying a fish to such an extent as to significantly disrupt normal behavioral patterns, including breeding, feeding, or sheltering and would not rise to the level of take.

Additionally, behavioral effects resulting from reactions to sound created by the airguns will be temporary (e.g., a startle response), and we do not expect these reactions to have any measurable effects on any individual's fitness. We expect individuals that exhibit a temporary behavioral response will return to pre-exposure behavior soon after the airgun array leaves the area. Similar to instances of TTS, we do not expect these short-term behavioral reactions to increase the likelihood of injury by annoying a fish to such an extent as to significantly disrupt normal behavioral patterns, including breeding, feeding, or sheltering and would not rise to the level of take.

Based on the evidence available, including the *Environmental Baseline, Effects of the Action* and *Cumulative Effects*, effects resulting from stressors caused by the National Science Foundation's seismic activities, or cumulatively for the reasonably foreseeable future (assuming there are no significant changes to the *Status of Listed Resources* or *Environmental Baseline*), would not be expected to appreciably reduce the likelihood of the survival of ESA-listed Coho salmon ESUs in the wild by reducing the reproduction, numbers, or distribution of the species or ESUs. Therefore, we do not anticipate any measurable or detectable reductions in the survival rate or trajectory of recovery of the Central California coast, Lower Columbia River, Oregon coast, and Southern Oregon & Northern California coast ESUs of Coho salmon.

12.1.13 Steelhead

Within the action area, ten DPSs of steelhead may be exposed to sound from the airgun array associated with the National Science Foundation's proposed seismic survey. These include the threatened California Central Valley DPS, Central California coast DPS, Lower Columbia River DPS, Middle Columbia River, Northern California DPS, Puget Sound DPS, Snake River Basin DPS, South-Central California Coast DPS, Upper Columbia River DPS, and Upper Willamette River DPS. Individuals exposed will be in the marine environment, and will be subadults or adults.

Listing dates for each of these steelhead DPSs are provided in Section 5. Primary threats to steelhead salmon include blocked access to spawning grounds, habitat degradation caused by dams and culverts, commercial fishing, and issues stemming from climate change (i.e., drought).

Any steelhead located within the ensonified area of the airgun array could be injured, sustain some degree of TTS or exhibit behavioral disruptions. Severity of injury would likely increase closer to the array, where impacts are more probable within a close distance.

As shown in Tables 60, 61, and 62, only a small annual percentage of each steelhead DPS would be injured or experience TTS due to the seismic activities.

The anticipated level of TTS and injury represents a very small reduction in abundance that is not likely to appreciably reduce the likelihood of survival and recovery of any ESA-listed steelhead. Additionally, we conclude that the diversity of ESA-listed steelhead populations will not be affected by this limited amount of take because it is expected to be distributed across populations through species' ranges in the ocean. As a result, the seismic activities the National

Science Foundation plans to conduct action area would not appreciably reduce the likelihood of ESA-listed Pacific steelhead surviving and recovering in the wild.

Some individual steelhead may experience TTS because of the seismic activities (i.e., impulsive acoustic stressors). However, the steelhead lack notable hearing specialization, minimizing the likelihood of each instance of TTS affecting an individual's fitness. These species are able to rely on alternative mechanisms (e.g., sight, lateral line system) to detect prey, avoid predators, spawn, and to orient in the water column (Popper et al. 2014a). Additionally, hearing is not thought to play a role in steelhead migration (e.g., Putnam et al. 2013). TTS is also short in duration with fish being able to replace hair cells when they are damaged (Lombarte et al. 1993; Smith et al. 2006). Because these species are able to rely on alternative mechanisms for essential life functions, instances of TTS would not increase the likelihood of injury by annoying a fish to such an extent as to significantly disrupt normal behavioral patterns, including breeding, feeding, or sheltering and would not rise to the level of take.

Additionally, behavioral effects on steelhead resulting from reactions to sound created by the seismic activities will be temporary (e.g., a startle response), and we do not expect these reactions to have any measurable effects on any individual's fitness. We expect individuals that exhibit a temporary behavioral response will return to pre-exposure behavior soon after the seismic activities conclude in an area. Similar to instances of TTS, we do not expect these short-term behavioral reactions to increase the likelihood of injury by annoying a fish to such an extent as to significantly disrupt normal behavioral patterns, including breeding, feeding, or sheltering and would not rise to the level of take.

Based on the evidence available, including the *Environmental Baseline, Effects of the Action* and *Cumulative Effects*, effects resulting from stressors caused by seismic activities the National Science Foundation will fund in the action area, or cumulatively for the reasonably foreseeable future (assuming there are no significant changes to the *Status of Listed Resources* or *Environmental Baseline*), would not be expected to appreciably reduce the likelihood of the survival of ESA-listed Pacific steelhead DPSs in the wild by reducing the reproduction, numbers, or distribution of the species or DPSs.

12.1.14 Sockeye

Within the action area, the endangered Snake River ESU and Ozette Lake ESU of sockeye salmon may be exposed to seismic activities. The listing date for these sockeye salmon ESUs are provided in Section 5. Individuals exposed will be in the marine environment, and will be subadults or adults. Threats to sockeye salmon include habitat impediments (dams), habitat degradation, habitat loss, commercial and recreational fishing, and impacts from climate change including drought.

As with other ESA-listed fishes in the action area, any sockeye salmon located within the ensonified area of the airgun array could be injured, sustain some degree of TTS, or exhibit behavioral disruptions. Severity of injury would likely increase closer to the array, where injury is more probable within a close distance of the airgun array. The maximum annual number of estimated injuries and TTS along with the proportion of sockeye salmon injured or experiencing TTS using abundances from NMFS (2020) from the Ozette Land and Snake River ESUs are presented in Tables 60, 61, and 62. As shown in Tables 60, 61, and 62, only a small annual percentage of Snake River and Ozette Lake sockeye salmon may be injured or experience TTS as a result of the seismic activities.

The anticipated level of TTS and injury represents a very small reduction in abundance that is not likely to appreciably reduce the likelihood of survival and recovery of any ESA-listed sockeye salmon. Additionally, we conclude that the diversity of ESA-listed sockeye salmon populations will not be affected by this limited amount of take because it is expected to be distributed across populations throughout species' ranges in the ocean. As a result, the seismic activities in the action area would not appreciably reduce the likelihood of ESA-listed sockeye salmon surviving and recovering in the wild.

Some individual sockeye salmon may experience TTS as a result of the seismic activities (i.e., impulsive acoustic stressors). However, sockeye salmon lack notable hearing specialization, minimizing the likelihood of each instance of TTS affecting an individual's fitness. These species are able to rely on alternative mechanisms (e.g., sight, lateral line system) to detect prey, avoid predators, spawn, and to orient in the water column (Popper et al. 2014a). Additionally, hearing is not thought to play a role in sockeye salmon migration (e.g., Putnam et al. 2013). TTS is also short in duration with fish being able to replace hair cells when they are damaged (Lombarte et al. 1993; Smith et al. 2006). Because these species are able to rely on alternative mechanisms for essential life functions, instances of TTS would not increase the likelihood of injury by annoying a fish to such an extent as to significantly disrupt normal behavioral patterns, including breeding, feeding, or sheltering and would not rise to the level of take.

Additionally, behavioral effects on sockeye salmon resulting from reactions to sound created by the airgun array will be temporary (e.g., a startle response), and we do not expect these reactions to have any measurable effects on any individual's fitness. We expect individuals that exhibit a temporary behavioral response will return to pre-exposure behavior soon after the seismic survey concludes in an area. Similar to instances of TTS, we do not expect these short-term behavioral reactions to increase the likelihood of injury by annoying a fish to such an extent as to significantly disrupt normal behavioral patterns, including breeding, feeding, or sheltering and would not rise to the level of take.

Based on the evidence available, including the *Environmental Baseline, Effects of the Action* and *Cumulative Effects*, effects resulting from stressors caused by the seismic activities, or cumulatively for the reasonably foreseeable future (assuming there are no significant changes to the *Status of Listed Resources* or *Environmental Baseline*), would not be expected to appreciably reduce the likelihood of the survival of the Ozette Lake or Snake River ESU of sockeye salmon in the wild by reducing the reproduction, numbers, or distribution of the species or ESUs.

Therefore, we do not anticipate any measurable or detectable reductions in survival rate or trajectory of recovery of the Ozette Lake or Snake River ESU of sockeye salmon.

12.1.15 Green Sturgeon—Southern Distinct Population Segment

Within the action area, the Southern DPS of green sturgeon may be exposed to sound from the airgun array associated with the National Science Foundation's proposed seismic survey. Individuals exposed will be in the marine environment, and will be subadults or adults.

The Southern DPS of green sturgeon was listed as a threatened species under the ESA in 2006 (71 FR 17757). The final rule listing Southern DPS green sturgeon indicates that the principle factor for the decline in the DPS is the reduction of spawning to a limited area in the Sacramento River caused primarily by impoundments. Green sturgeon also face threats related to water temperature, water flow, and from commercial and recreational fishing bycatch. Climate change has the potential to impact Southern DPS green sturgeon in the future, but it is unclear how changing oceanic, nearshore and river conditions will affect the Southern DPS overall (NMFS 2015f).

Based on the best available information, the current population abundance estimate for the Southern DPS green sturgeon is 4,387 juveniles, 11,055 subadults, and 2,106 adults (Mora et al. 2018). No estimate of intrinsic growth rates are available for Southern DPS green sturgeon. Attempts to evaluate the status of Southern DPS green sturgeon have been met with limited success due to the lack of reliable long-term data.

With the exception of acoustic stressors, we found that the effects all other potential stressors (i.e., vessel strike, pollution, operational noise and visual disturbance, and gear interaction) analyzed in this opinion on Southern DPS green sturgeon were either discountable or insignificant (see Section 7). From our fish exposure analysis (Section 10.2.1.4), we were not able to quantify the amount of expected take for Southern DPS green sturgeon, and rely on the extent of take based the 187 dB ensonified area.

As described in 10.2.1.4, green sturgeon tend to occupy shallow water (less than 70 meters deep). Based on the location of the tracklines and the resulting ensonified areas, we expect that if Southern DPS green surgeon are in the areas of the survey off Oregon, they are most likely to experience the stressors associated with the seismic survey. The survey will not take place in waters less than 100 meters deep off the coast of Washington and Vancouver Island, so we expect it to be less likely that exposure of Southern DPS green sturgeon would occur in those areas.

We do not expect the proposed action to result in mortality of Southern DPS green sturgeon. The proposed action is likely to result in sublethal effects on Southern DPS green sturgeon including behavioral responses, TTS, and sublethal injuries. As noted above (Section 9.3.1.5), because green sturgeon are not known to rely on hearing for essential life functions, and any effects from TTS would likely be short-term and temporary, and instances of TTS would not likely result in measurable effects on any individual's fitness. Similarly, behavioral effects on green sturgeon resulting from reactions to sound created by the seismic activities will be temporary (e.g., a startle response), and we do not expect these reactions to have any measurable effects on any individual's fitness. Some proportion of sub-lethal injuries from the seismic activities would likely result in fitness consequences for individual green sturgeon exposed. With an estimated subadult/adult population size of 13,161 (Mora et al. 2018), and an overall low expected amount of exposure, and the short duration of the survey in shallow areas (less than 100 meters), we do not believe the Southern DPS green sturgeon population would experience fitness consequences as a result of the proposed action. In addition, considering their size, longevity and low rate of natural mortality, we would expect most subadult and adult green sturgeon to recover from sublethal injuries with little or no long-term effect on their survival or future reproductive potential.

In summary, we anticipate Southern DPS green sturgeon subadults and adults would be adversely affected because of the proposed action, with the likely effects including sub-lethal injury, temporary hearing loss, and behavioral harassment. While the serious injury of individuals would likely have adverse effects on this threatened population, the population level impacts are not anticipated to result in appreciable reductions in overall reproduction, numbers, or distribution of this species. Based on the evidence available, including the *Environmental Baseline, Effects of the Action* and *Cumulative Effects*, effects resulting from stressors caused by the proposed seismic survey, or cumulatively for the reasonably foreseeable future (assuming there are no significant changes to the *Status of Listed Resources* or *Environmental Baseline*), would not be expected to appreciably reduce the likelihood of the survival of the Southern DPS green sturgeon in the wild by reducing the reproduction, numbers, or distribution of the DPS. Therefore, we do not anticipate any measurable or detectable reductions in survival rate or trajectory of recovery of the Southern DPS green sturgeon.

12.1.16 Eulachon—Southern Distinct Population Segment

Within the action area, Southern DPS eulachon may be exposed to sound associated with seismic activities. Individuals exposed will be in the marine environment, and will be subadults or adults. Southern DPS eulachon was listed as threatened in October 20, 2011. The primary threats facing Southern DPS eulachon include habitat degradation, habitat impediments, water pollution, and fisheries interaction.

As with other ESA-listed fishes in the action area, any Southern DPS eulachon located within the ensonified area of the airgun array could be injured, sustain some degree of TTS, or exhibit behavioral disruptions. Severity of injury would likely increase closer to the airgun array, where injury is more probable within a closer distance of the airgun array. The number of estimated injuries and TTS, along with the proportion of Southern DPS eulachon injured or experiencing TTS using abundances from NMFS (2020), are presented in 10.2.1.4.

Only an extremely small annual percentage (less than 0.004 percent) of the Southern DPS eulachon may be injured or experience TTS by the seismic activities. This level of TTS and injury represents an extremely small amount of the overall population that is not likely to appreciably reduce the likelihood of survival and recovery Southern DPS eulachon. Additionally, we conclude that the diversity of ESA-listed eulachon populations will not be affected by this limited amount of take because it is expected to be distributed across populations through species' ranges in the ocean. As a result, the seismic activities in the action area would not appreciably reduce the likelihood of ESA-listed eulachon surviving and recovering in the wild.

Some individual eulachon may experience TTS because of the seismic activities (i.e., impulsive acoustic stressors). However, eulachon lack notable hearing specialization, minimizing the likelihood of each instance of TTS affecting an individual's fitness. These species are able to rely on alternative mechanisms (e.g., sight, lateral line system) to detect prey, avoid predators, spawn, and to orient in the water column (Popper et al. 2014a). Additionally, hearing is not thought to play a role in eulachon migration (e.g., Putnam et al. 2013). TTS is also short in duration with fish being able to replace hair cells when they are damaged (Lombarte et al. 1993; Smith et al. 2006). Because these species are able to rely on alternative mechanisms for essential life functions, instances of TTS would not increase the likelihood of injury by annoying a fish to such an extent as to significantly disrupt normal behavioral patterns, including breeding, feeding, or sheltering and would not rise to the level of take.

Additionally, behavioral effects on eulachon resulting from reactions to sound created by the airguns will be temporary (e.g., a startle response), and we do not expect these reactions to have any measurable effects on any individual's fitness. We expect individuals that exhibit a temporary behavioral response will return to pre-exposure behavior soon after the airgun array leaves the area. Similar to instances of TTS, we do not expect these short-term behavioral reactions to increase the likelihood of injury by annoying a fish to such an extent as to significantly disrupt normal behavioral patterns, including breeding, feeding, or sheltering and would not rise to the level of take.

Based on the evidence available, including the *Environmental Baseline, Effects of the Action* and *Cumulative Effects*, effects resulting from stressors caused by the National Science Foundation's seismic survey, or cumulatively for the reasonably foreseeable future (assuming there are no significant changes to the *Status of Listed Resources* or *Environmental Baseline*), would not be expected to appreciably reduce the likelihood of the survival and recovery of Southern DPS eulachon in the wild by reducing the reproduction, numbers, or distribution of the species or DPSs. Therefore, we do not anticipate any measurable or detectable reductions in survival rate or trajectory of recovery of the Southern DPS eulachon.

13 Conclusion

After reviewing the current status of the ESA-listed species, the environmental baseline within the action area, the effects of the proposed action, and cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of: blue whale, fin whale, humpback whale (Central America DPS and Mexico DPSs), sei whale, killer whale (Southern Resident DPS), sperm whales, Guadalupe fur seal, leatherback sea turtle, Pacific eulachon (Southern DPS), green sturgeon (Southern DPS), Chinook salmon (Sacramento River winter-run, Central valley spring-run, California coastal, Snake River fall-run, Snake River spring/summer-run, Lower Columbia River, Upper Willamette River, Upper Columbia River spring-run, and Puget Sound ESUs), chum salmon (Hood Canal summer-run and Columbia River ESUs), Coho salmon (Central California coast, Southern Oregon and Northern California coast, Lower Columbia River, and Oregon Coast ESUs), sockeye salmon (Snake River ESU), and steelhead (South-Central California Coast, Central California Coast, California Central Valley, Northern California, Upper Columbia River, Snake River Basin, Lower Columbia River, Upper Willamette River, Middle Columbia River, and Puget Sound DPSs).

It is also NMFS' biological opinion that the action is not likely to adversely affect the following ESA-listed species and designated and proposed critical habitat: blue whales; fin whales; the Mexico DPS or Central America DPS of humpback whales; sei whales; sperm whales; Southern Resident distinct population segment (DPS) killer whales; Guadalupe fur seals; leatherback sea turtles; Southern DPS of green sturgeon; southern DPS of eulachon; and ESA-listed evolutionary significant units (ESUs) of California Coastal ESU, Central Valley Spring-Run ESU, Lower Columbia River ESU, Puget Sound ESU, Sacramento River Winter-Run ESU, Snake River Fall-Run, Snake River Spring/Summer-Run ESU, Upper Columbia River Spring-Run ESU, and Upper Willamette River ESU Chinook, Columbia River ESU and Hood Canal Summer-Run ESU chum, Central California Coast ESU, Lower Columbia River ESU, Oregon Coast ESU, and Southern Oregon and Northern California Coasts ESU Coho, Ozette Lake ESU and Snake River ESU sockeye salmon, and Central Valley ESU, Central California Coast ESU, Lower Columbia River ESU, Middle Columbia River ESU Northern California DPS, Puget Sound DPS, Snake River Basin DPS, South-Central California Coast DPS, Upper Columbia River DPS, Upper Willamette River DPS steelhead trout.

14 Incidental Take Statement

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by regulation to include significant habitat modification or degradation that results in death or injury to ESA-listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering.

Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this incidental take statement.

14.1 Amount or Extent of Take

Section 7 regulations require NMFS to specify the impact of any incidental take of endangered or threatened species; that is, the amount or extent, of such incidental taking on the species (50 C.F.R. §402.14(i)(1)(i)). The amount of take represents the number of individuals that are expected to be taken by actions while the extent of take specifies the impact, i.e., the amount or extent of such incidental taking on the species, which may be used if we cannot assign numerical limits for animals that could be incidentally taken during the course of an action (see 80 FR 26832).

If the amount or location of tracklines during the seismic survey changes, or the number of seismic survey days is increased, then incidental take for marine mammals and sea turtles may be exceeded. As such, if more tracklines are conducted during the seismic survey, an increase in the number of days beyond the 25 percent contingency, greater estimates of sound propagation, and/or increases in airgun array source levels occur, reinitiation of consultation will be necessary.

14.1.1 Marine Mammals

We anticipate noise from seismic survey activities is reasonably likely to result in the incidental take of ESA-listed marine mammals by injury or harassment. Specifically, we anticipate the take of marine mammals in the action area as detailed in Table 63 below.

Table 62. Estimated amount of incidental take of Endangered Species Act-listed marine mammals authorized in the Northeast Pacific Ocean by the incidental take statement.

Species	Authorized Incidental Take by Harassment (Potential Temporary Threshold Shift and Behavioral)	Authorized Incidental Take by Harm (Permanent Threshold Shift)
Blue Whale	40	11
Fin Whale	94	1
Humpback Whale – Central America DPS	42	11
Humpback Whale – Mexico DPS	34	9
Sei Whale	30	2
Sperm Whale	72	0
Southern Resident Killer Whale	10	0
Guadalupe Fur Seal	2048	0

DPS=Distinct Population Segment

14.1.2 Sea Turtles

We anticipate noise from seismic survey activities is reasonably likely to result in the incidental take of ESA-listed leatherback sea turtles by harassment. Specifically, we anticipate the take of three leatherback sea turtles in the action area.

14.1.3 Fishes

We anticipate noise from seismic survey activities is reasonably likely to result in the incidental take of ESA-listed fish by injury or harassment. Specifically, we anticipate the take of fish in the action area as detailed in Table 64 below.

Table 63. Expected amount of incidental take of Endangered Species Act-listed fishes authorized in the Northeast Pacific Ocean by the incidental take statement.

Species	Life stage	ESU/DPS	Natural		Hatchery: adipose clip[3]		Hatchery: adipose intact	
			TTS	Injury	TTS	Injury	TTS	Injury
Chinook salmon	Adult	Sac River winter run - E	72	5	770	49	-	-
	Juvenile		22,451	1,439	22,985	1,473	-	-
	Adult	Central valley spring run - T	1,285	82	784	50	-	-
	Juvenile		89,120	5,710	249,307	15,974	-	-
	Adult	California coastal - T	4,665	299	-	-	-	-
	Juvenile		282,538	18,103	-	-	-	-
	Adult	Snake River fall - T	670	43	1,006	64	879	56
	Juvenile		14,979	960	53,698	3,441	61,886	3,965
	Adult	Snake River spring/summer - T	830	53	155	10	27	2
	Juvenile		21,783	1,396	96,289	6,170	16,762	1,074
	Adult[4]	Lower Columbia River - T	2,236	143	-	-	2,928	188
	Juvenile		297,042	19,033	792,955	50,808	19,090	1,560
	Adult[4]	Upper Willamette River - T	686	44	-	-	2,116	136
	Juvenile		27,162	1,740	105,547	6,763	4	-

	Adult	Upper Columbia River spring - E	186	12	404	26	218	14
	Juvenile		10,136	649	13,443	861	7,970	511
	Adult[4]	Puget Sound - T	3,954	253	-	-	2,744	176
	Juvenile		178,605	11,444	2,135,854	136,852	427,855	27,414
Coho salmon	Adult	Central California coast - E	1,101	71	-	-	186	12
	Juvenile		45,049	2,886	-	-	47,257	3,028
	Adult[4]	S. Oregon/N. California coast - T	1,419	91	-	-	1,712	110
	Juvenile		157,644	10,101	15,658	1,003	45,017	2,884
	Adult	Oregon coast - T	20,365	1,305	121	8	-	-
	Juvenile		717,012	45,942	6,477	415	-	-
	Adult	Lower Columbia River - T	7,986	512	-	-	2,351	151
	Juvenile		88,441	5,667	974,391	62,433	33,397	2,140
Chum salmon	Adult	Hood Canal summer run	241	15	-	-	14	1
	Juvenile		12,449	798	-	-	480	31
	Adult	Columbia River - T	102	7	-	-	4	-
	Juvenile		21,206	1,359	-	-	1,925	123
Sockeye salmon	Adult	Ozette Lake - T	5	-	38	2	-	-
	Juvenile		61	4	776	50	-	-
	Adult	Snake River - E	2	-	-	-	-	-
	Juvenile		84	5	-	-	-	-
Steelhead	Adult	South-Central California - T	7	-	-	-	-	-
	Juvenile		265	5	-	-	-	-
	Adult	Central California - T	5	-	12	1	-	-
	Juvenile		672	17	692	44	-	-
	Adult	California Central Valley - T	23	1	12	1	-	-
	Juvenile		876	56	1,706	109	-	-
	Adult		5	1	-	-	-	-

	Juvenile	Northern California - T	672	43	-	-	9	0
	Adult	Upper Columbia River - E	23	1	17	1	3	0
	Juvenile		876	56	733	47	48	0
	Adult	Snake River basin - T	6	-	254	16	5	0
	Juvenile		213	14	3,518	225	1	0
	Adult[4]	Lower Columbia River - T	34	2	-	-	-	-
	Juvenile		851	55	1,276	82	-	-
	Adult	Upper Willamette River - T	41	3	-	-	-	-
	Juvenile		375	24	-	-	8	0
	Adult	Middle Columbia River - T	9	3	1	-	-	-
	Juvenile		150	24	474	30	8	0
	Adult[5]	Puget Sound - T	16	1	-	-	-	-
	Juvenile		435	28	117	8	-	-
Eulachon	Adult	Southern – T	708,515	39,179	-	-	-	-

[3] It should be noted that ESA take prohibitions do not apply to hatchery fish with clipped adipose fins from threatened ESUs or DPSs
[4] Hatchery intact adipose mortality and injury estimates comprise of hatchery fish with intact and clipped adipose fins.
[5] Includes natural and hatchery (clipped and intact adipose fish) estimates.

We also expect Southern DPS green sturgeon could be exposed to sounds from the airgun arrays during the course of the proposed seismic surveys that could result in TTS or injury. No death is expected for any individual green sturgeon exposed to seismic survey activities. NMFS anticipates the proposed seismic survey is likely to result in the incidental take of Southern DPS green sturgeon by TTS or injury.

Where it is not practical to quantify the number of individuals that are expected to be taken by the action, a surrogate (e.g., similarly affected species, habitat, ecological conditions, and sound pressure thresholds) may be used to express the amount or extent of anticipated take (50 CFR 402. §14(i)(1)(i)). Because there are no reliable estimates of Southern DPS green sturgeon population densities in the action area, , it is not practical to develop numerical estimates of green sturgeon exposure. We are relying on the extent of the 187 dB re: 1 μPa (rms) ensonified areas. A green sturgeon within the 187 dB re: 1 μPa (rms) during airgun array operations will be affected by the stressor, and is expected to respond in a manner that constitutes take.

If the amount or location of trackline surveyed changes, or the number of seismic survey days is increased, then incidental take for green sturgeon may be exceeded. As such, if more tracklines are surveyed, there is an increase in the number of survey days beyond the 25 percent contingency, there are greater estimates of sound propagation, and/or increases in source levels from the airgun array occur, re-initiation of consultation will be necessary.

14.2 Reasonable and Prudent Measures

The measures described below are nondiscretionary, and must be undertaken by the National Science Foundation and the NMFS Permits and Conservation Division so that they become binding conditions for the exemption in section 7(o)(2) to apply. Section 7(b)(4) of the ESA requires that when a proposed agency action is found to be consistent with section 7(a)(2) of the ESA and the proposed action may incidentally take individuals of ESA-listed species, NMFS will issue a statement that specifies the impact of any incidental taking of endangered or threatened species. To minimize such impacts, reasonable and prudent measures, and term and conditions to implement the measures, must be provided. Only incidental take resulting from the agency actions and any specified reasonable and prudent measures, and terms and conditions identified in the incidental take statement are exempt from the taking prohibition of section 9(a), pursuant to section 7(o) of the ESA.

Reasonable and prudent measures are nondiscretionary measures to minimize the amount or extent of incidental take (50 C.F.R. §402.02). NMFS believes the reasonable and prudent measures described below are necessary and appropriate to minimize the impacts of incidental take on the ESA-listed marine mammals, fish, and leatherback sea turtles discussed in detail in this opinion:

- The NMFS Permits and Conservation Division must ensure that the National Science Foundation and L-DEO implement a program to mitigate and report the potential effects of seismic survey activities as well as the effectiveness of mitigation measures incorporated as part of the proposed incidental harassment authorization for the incidental taking of blue, fin, Central America DPS of humpback, Mexico DPS of humpback, sei, and sperm whales and Guadalupe fur seals pursuant to section 101(a)(5)(D) of the MMPA and as specified below for leatherback turtles and fishes (i.e., the monitoring requirements). In addition, the NMFS Permits and Conservation Division must ensure that the provisions of the incidental harassment authorization are carried out, and to inform the NMFS ESA Interagency Cooperation Division if take is exceeded.
- The NMFS Permits and Conservation Division must ensure that the National Science Foundation and L-DEO implement a program to monitor and report any potential interactions between seismic survey activities and threatened and endangered species of marine mammals.
- The National Science Foundation and the L-DEO must implement a program to mitigate and report the potential effects of seismic survey activities as well as the effectiveness of mitigation measures for endangered and threatened leatherback sea turtles and fishes.

14.3 Terms and Conditions

To be exempt from the prohibitions of section 9 of the ESA and regulations issued pursuant to section 4(d), the National Science Foundation, L-DEO and NMFS Permits and Conservation Division must comply with the following terms and conditions, which implement the RPMs described above. These include the take minimization, monitoring and reporting measures required by the section 7 regulations (50 C.F.R. §402.14(i)). If the National Science Foundation, L-DEO and NMFS Permits and Conservation Division fail to ensure compliance with these terms and conditions to implement the RPMs applicable to the authorities of the agencies, the protective coverage of section 7(o)(2) may lapse.

The terms and conditions detailed below for each of the RPMs include monitoring and minimization measures where needed:

1. A copy of the draft comprehensive report on all seismic survey activities and monitoring results must be provided to the ESA Interagency Cooperation Division within 90 days of the completion of the seismic survey, or expiration of the incidental harassment authorization, whichever comes sooner.
2. Any reports of injured or dead ESA-listed species must be provided by the L-DEO and NSF to the ESA Interagency Cooperation Division within 24 hours to Cathy Tortorici, Chief, ESA Interagency Cooperation Division by e-mail at cathy.tortorici@noaa.gov.

15 Conservation Recommendations

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on ESA-listed species or critical habitat, to help implement recovery plans or develop information (50 C.F.R. §402.02).

We recommend the following discretionary conservation recommendations that we believe are consistent with this obligation and therefore may be considered by NSF and the NMFS Permits and Conservation Division in relation to their 7(a)(1) responsibilities. These recommendations will provide information for future consultations involving seismic surveys and the issuance of IHAs that may affect ESA-listed species:

1. We recommend that the National Science Foundation promote and fund research examining the potential effects of seismic surveys on ESA-listed sea turtle and fish species.
2. We recommend that the National Science Foundation develop a more robust propagation model that incorporates environmental variables into estimates of how far sound levels reach from airgun arrays.
3. We recommend that the National Science Foundation conduct a sound source verification in the study area (and future locations) to validate predicted and modeled isopleth

distances to ESA harm and harassment thresholds and incorporate the results of that study into buffer and exclusion zones prior to starting seismic survey activities.

4. We recommend that the NMFS Permits and Conservation Division develop a flow chart with decision points for mitigation and monitoring measures to be included in future MMPA incidental take authorizations for seismic surveys.
5. We recommend the National Science Foundation use (and NMFS Permits and Conservation Division require in MMPA incidental take authorizations) thermal imaging cameras, in addition to binoculars (Big-Eye and handheld) and the naked eye, for use during daytime and nighttime visual observations and test their effectiveness at detecting ESA-listed species.
6. We recommend the National Science Foundation use the Marine Mammal Commission's recommended method for estimating the number of cetaceans in the vicinity of seismic surveys based on the number of groups detected for post-seismic survey activities take analysis and use in monitoring reports.
7. We recommend the National Science Foundation and NMFS Permits and Conservation Division work to make the data collected as part of the required monitoring and reporting available to the public and scientific community in an easily accessible online database that can be queried to aggregate data across protected species observer reports. Access to such data, which may include sightings as well as responses to seismic survey activities, will not only help us understand the biology of ESA-listed species (e.g., their range), it will inform future consultations and incidental take authorizations/permits by providing information on the effectiveness of the conservation measures and the impact of seismic survey activities on ESA-listed species.
8. We recommend the National Science Foundation and NMFS Permits and Conservation Division consider using the potential standards for towed array passive acoustic monitoring in the *Towed Array Passive Acoustic Operations for Bioacoustic Applications: ASA/JNCC Workshop summary March 14-18, 2016 Scripps Institution of Oceanography, La Jolla, California, USA* (Thode 2017).
9. We recommend the National Science Foundation use real-time cetacean sighting services such as the WhaleAlert application (http://www.whalealert.org/). We recognize that the research vessel may not have reliable internet access during operations far offshore, but nearshore, where many of the cetaceans considered in this opinion are likely found in greater numbers, we anticipate internet access may be better. Monitoring such systems will help plan seismic survey activities and transits to avoid locations with recent ESA-listed cetacean sightings, and may also be valuable during other activities to alert others of ESA-listed cetaceans within the area, which they can then avoid.
10. We recommend the National Science Foundation submit their monitoring data (i.e., visual sightings) by PSOs to the Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations online database so that it can be

added to the aggregate marine mammal, seabird, sea turtle, and fish observation data from around the world.

11. We recommend the vessel operator and other relevant vessel personnel (e.g., crewmembers) on the R/V *Marcus G. Langseth* take the U.S. Navy's marine species awareness training available online at: https://www.youtube.com/watch?v=KKo3r1yVBBA in order to detect ESA-listed species and relay information to PSOs.

In order for NMFS' Office of Protected Resources ESA Interagency Cooperation Division to be kept informed of actions minimizing or avoiding adverse effects on, or benefiting, ESA-listed species or their critical habitat, the NMFS Permits and Conservation Division should notify the ESA Interagency Cooperation Division of any conservation recommendations they implement in their final action.

16 Reinitiation Notice

This concludes formal consultation for the National Science Foundation and L-DEO's proposed high-energy marine seismic survey by the R/V *Marcus G. Langseth* in the Northeast Pacific Ocean and NMFS Permits and Conservation Division's issuance of an incidental harassment authorization for the proposed high-energy marine seismic survey pursuant to section 101(a)(5)(D) of the MMPA. Consistent with 50 C.F.R. §402.16, reinitiation of formal consultation is required and shall be requested by the Federal agency or by the Service, where discretionary Federal agency involvement or control over the action has been retained or is authorized by law and:

1. The amount or extent of taking specified in the incidental take statement is exceeded.
2. New information reveals effects of the agency action that may affect ESA-listed species or critical habitat in a manner or to an extent not previously considered.
3. The identified action is subsequently modified in a manner that causes an effect to ESA-listed species or designated critical habitat that was not considered in this opinion.
4. A new species is listed or critical habitat designated under the ESA that may be affected by the action.

If the amount of tracklines, location of tracklines, acoustic characteristics of the airgun arrays, timing of the survey, or any other aspect of the proposed action changes in such a way that the incidental take of ESA-listed species can be greater than estimated in the incidental take statement of this opinion, then one or more of the reinitiation triggers above may be met and reinitiation of consultation may be necessary.

17 Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response

Section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. Under the MSA, this consultation is intended to promote the conservation of EFH as necessary to support sustainable fisheries and the managed species' contribution to a healthy ecosystem. For the purposes of the MSA, EFH means "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity", and includes the physical, biological, and chemical properties that are used by fish (50 C.F.R. §600.10). Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside of it and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 C.F.R. §600.810). Section 305(b) of the MSA also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH. Such recommendations may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects of the action on EFH [50 C.F.R. §600.905(b)]

This analysis is based, in part, on the descriptions of EFH for Pacific Coast groundfish (PFMC 2005), coastal pelagic species (PFMC 1998), Pacific Coast salmon (PFMC 2014), and highly migratory species (PFMC (2007) contained in the fishery management plans developed by the Pacific Fishery Management Council (PFMC) and approved by the Secretary of Commerce.

17.1 Essential Fish Habitat Affected by the Project

The proposed action and action area for this consultation are described in the ESA sections of this document (Sections 3 and 4). The action area includes areas designated as EFH for various life-history stages of Pacific Coast groundfish, coastal pelagic species, Pacific Coast salmon, and highly migratory species (PFMC 2005, PFMC 1998, PFMC 2014, PFMC 2008). In addition, the action area includes many Habitat Areas of Particular Concern (HAPC) for Pacific Coast groundfish EFH.[28] Rocky reefs (those waters, substrates and other biogenic features associated with hard substrate) and canopy kelp (those waters, substrate, and other biogenic habitat associated with canopy-forming kelp species) are HAPCs because of their importance to many species managed by the PFMC. Areas of interest are discrete areas that are of special interest due to their unique geological and ecological characteristics.

17.2 Adverse Effects on Essential Fish Habitat

The ESA effects analysis (sections 5 and 9) describes the adverse effects of this proposed action on several ESUs and DPSs. Some of the species covered in the ESA effects analysis are also

[28] See: https://archive.fisheries.noaa.gov/wcr/publications/gis_maps/maps/groundfish/map-gfish-hapc.pdf

species covered under the MSA and that have designated EFH. Notably, the Chinook salmon and Coho salmon ESA analyses are relevant to Pacific Coast salmon EFH. Because of the breadth of species covered in this opinion, we are also reasonably certain the ESA effects analysis is relevant to the effects on EFH.

The ESA Biological and Conference Opinion, Section 6, analyzed several potential stressors, including:

1. Pollution;
2. Vessel strike;
3. Operational noise and visual disturbance of vessels and equipment;
4. Gear interaction; and
5. Sound fields produced by airgun array, multi-beam echosounder, sub-bottom profiler, and acoustic Doppler current profiler.

The ESA analysis found only one stressor was likely to adversely affect ESA-listed species, sound fields produced by the airgun array, multi-beam echosounder, and sub-bottom profiler, and acoustic Doppler current profiler. Based on information developed in the ESA effects analysis, we conclude the effects from these sound fields constitute an adverse effect to Pacific Coast salmon, Pacific Coast groundfish, coastal pelagic species, and highly migratory species' EFH, and HAPCs for Pacific Coast groundfish.

While the ESA analysis of effects is relevant to EFH, the effects to some of the species protected under the MSA will be more severe. In particular, northern anchovy and Pacific sardine (included in the coastal pelagic species fishery management plan) have swim bladders connected to the inner ear for enhanced hearing (Ladich and Schulz-Mirbach 2016). This puts them in a category more sensitive to sound effects (Popper et al. 2014a).

In addition, as noted previously, rocky reefs are a designated HAPC and are preferred habitat for a number of Federally-managed species. Rockfish (*Sebastes* spp.) in particular exhibit strong affinities for hard substrate and even specific locations (Love et al. 2002; PFMC 2005). Moreover, hard bottom habitat provides an attachment surface, which is important for canopy kelp (also a HAPC) and most deep-sea corals, and has also been strongly associated with many sponge taxa (Huff et al. 2013). Deep-sea corals and sponges contribute significantly to biodiversity, serve an important ecological function for benthic communities, and enhance the diversity and structural component of fish habitat (Tissot et al. 2006, Henry et al. 2013). Direct impacts to these sensitive habitats could result from the deployment of anchoring systems.

17.3 Essential Fish Habitat Conservation Recommendations

Some impacts to EFH have already been minimized as part of the proposed action, or cannot be minimized. We determined that the following eight EFH conservation recommendations are necessary to avoid, minimize, mitigate, or otherwise offset the impact of the proposed action on EFH.

The action agencies should minimize adverse effects from sound fields produced by the proposed action by implementing the following recommendations:

1. NSF should ensure that all benthic habitat types throughout the project area are accurately delineated and mapped. It is particularly important to identify and delineate sensitive habitats, such as HAPCs and deep-sea corals.
2. NSF should avoid sensitive habitats (e.g., HAPCs, deep-sea corals) to the greatest extent practicable when deploying anchoring systems. The following NOAA Deep-Sea Coral and Sponge Map Portal contains information regarding observed coral and sponge locations within the Action Area: https://www.ncei.noaa.gov/maps/deep-sea-corals/mapSites.htm.
3. Much of the research available to date on the effects of seismic survey methods and how to minimize and mitigate those effects have been focused on marine mammals, not fish, and benthic invertebrates. Therefore, NSF should promote and fund research examining the potential effects of seismic surveys on EFH. Additional research and monitoring should be undertaken to gain a better understanding of the potential effects these seismic surveys may have on EFH, federally managed species, their prey and other NMFS trust resources. This research should be a component of future NSF funded seismic survey activities. This will aid in the development of site and project specific EFH conservation recommendations for future projects, as appropriate.
4. NSF should develop a more robust propagation model that incorporates environmental variables into estimates of how far elevated sound levels extend from airgun arrays.
5. NSF should conduct a sound source verification in the study area (and future locations) to validate predicted and modeled isopleth distances to effect thresholds and incorporate the results of that study into buffer and exclusion zones prior to starting seismic survey activities.
6. NSF should submit their monitoring data (i.e., visual sightings) by PSOs to the Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations online database so that it can be added to the aggregate marine mammal, seabird, sea turtle, and fish observation data from around the world.
7. The vessel operator and other relevant vessel personnel (e.g., crewmembers) on the R/V *Marcus G. Langseth* take the U.S. Navy's marine species awareness training available online at: https://www.youtube.com/watch?v=KKo3r1yVBBA in order to detect ESA-listed species that are also included in fishery management plans and have EFH in the action area and relay information to PSOs.

The action agencies should ensure completion of a monitoring and reporting program to confirm the program is meeting the objective of limiting adverse effects to EFH by implementing the following:

8. NSF and NMFS Permits and Conservation Division should provide a copy of the draft comprehensive report on all seismic survey activities and monitoring results to the ESA

Interagency Cooperation Division and the West Coast Region EFH Office within 90 days of the completion of the seismic survey.

17.4 Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the NSF and NMFS Permits and Conservation Division must provide a detailed response in writing to us within 30 days after receiving EFH Conservation Recommendations. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of our EFH Conservation Recommendations unless the Federal agencies and we have agreed to use alternative time frames for the Federal agency response. The response must include a description of the measures proposed by the agency for avoiding, minimizing, mitigating, or otherwise offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the Conservation Recommendations, the Federal agencies must explain their reasons for not following the recommendations, including the scientific justification for any disagreements with us over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)).

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, we established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we ask that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

17.5 Supplemental Consultation

The NSF and NMFS Permits and Conservation Division must reinitiate EFH consultation with us if the proposed action is substantially revised in a way that may adversely affect EFH, or if new information becomes available that affects the basis for our EFH Conservation Recommendations (50 CFR 600.920(l)).

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19 APPENDICES

Appendix A

INCIDENTAL HARASSMENT AUTHORIZATION

The Lamont-Doherty Earth Observatory of Columbia University (L-DEO) is hereby authorized under section 101(a)(5)(D) of the Marine Mammal Protection Act (MMPA; 16 U.S.C. 1371(a)(5)(D)) to harass marine mammals incidental to a geophysical survey in the Northeast Pacific Ocean, when adhering to the following terms and conditions.

1. This Incidental Harassment Authorization (IHA) is valid for a period of one year from the date of issuance.

2. This IHA is valid only for geophysical survey activity as specified in L-DEO's IHA application and using an array aboard the R/V *Langseth* with characteristics specified in the IHA application, in the Northeast Pacific Ocean along the Cascadia Subduction Zone.

3. General Conditions

   (a) A copy of this IHA must be in the possession of L-DEO, the vessel operator, the lead protected species observer (PSO) and any other relevant designees of L-DEO operating under the authority of this IHA.

   (b) The species authorized for taking are listed in Table 1. The taking, by Level A and Level B harassment only, is limited to the species and numbers listed in Table 1.

   (c) The taking by serious injury or death of any of the species listed in Table 1 or any taking of any other species of marine mammal is prohibited and may result in the modification, suspension, or revocation of this IHA. Any taking exceeding the authorized amounts listed in Table 1 is prohibited and may result in the modification, suspension, or revocation of this IHA.

   (d) During use of the acoustic source, if any marine mammal species that are not listed in Table 1 appear within or enter the Level B harassment zone (Table 2) or a species for which authorization has been granted but the takes have been met, is observed within or approaching the Level A or Level B harassment zones (Tables 2-3), the acoustic source must be shut down.

   (e) L-DEO must ensure that relevant vessel personnel and PSO team participate in a joint onboard briefing led by the vessel operator and lead PSO to ensure that responsibilities, communication procedures, protected species monitoring protocols, operational procedures, and IHA requirements are clearly understood.

4. Mitigation Measures

   The holder of this Authorization is required to implement the following mitigation measures:

   (a) L-DEO must use independent, dedicated, trained visual and acoustic PSOs, meaning that the PSOs must be employed by a third-party observer provider, must not have tasks other than to conduct observational effort, collect data, and communicate with and instruct relevant vessel crew with regard to the presence of protected species and mitigation requirements (including brief alerts regarding maritime hazards), and must have successfully completed an approved PSO training course appropriate for their designated task (visual or acoustic). Individual PSOs may perform acoustic and visual PSO duties (though not at the same time).

   (b) At least one visual and two acoustic PSOs aboard the R/V *Langseth* and at least one visual PSO aboard the second vessel (see condition 4(c)(iii)) must have a minimum of 90 days at-sea experience working in those roles, respectively, during a deep penetration seismic survey, with no more than 18 months elapsed since the conclusion of the at-sea experience.

(c) Visual Observation

(i) During survey operations *(e.g.*, any day on which use of the acoustic source is planned to occur, and whenever the acoustic source is in the water, whether activated or not), a minimum of two PSOs must be on duty and conducting visual observations at all times during daylight hours (*i.e.*, from 30 minutes prior to sunrise through 30 minutes following sunset) and 30 minutes prior to and during ramp-up of the airgun array. Visual monitoring of the exclusion and buffer zones must begin no less than 30 minutes prior to ramp-up and must continue until one hour after use of the acoustic source ceases or until 30 minutes past sunset.

(ii) Visual PSOs must coordinate to ensure 360° visual coverage around the vessel from the most appropriate observation posts, and must conduct visual observations using binoculars and the naked eye while free from distractions and in a consistent, systematic, and diligent manner. Estimated harassment zones are provided in Tables 2-3 for reference.

(iii) During survey operations in water depths shallower than 200 m between Tillamook Head, Oregon (45.9460903° N) and Barkley Sound, British Columbia (48.780291° N), and while surveying within Olympic Coast National Marine Sanctuary, a second vessel with additional visual PSOs must accompany the R/V *Langseth* and survey approximately 5 km ahead of the R/V *Langseth*. Two visual PSOs must be on watch on the second vessel during all such survey operations (according to the requirements provided in 4(c)(i) of this IHA) and communicate all observations of marine mammals to PSOs on the R/V *Langseth*.

(iv) Visual PSOs must immediately communicate all observations to the acoustic PSO(s) on duty, including any determination by the PSO regarding species identification, distance, and bearing and the degree of confidence in the determination.

(v) During good conditions (*e.g.*, daylight hours; Beaufort sea state (BSS) 3 or less), visual PSOs must conduct observations when the acoustic source is not operating for comparison of sighting rates and behavior with and without use of the acoustic source and between acquisition periods, to the maximum extent practicable.

(vi) Visual PSOs may be on watch for a maximum of four consecutive hours followed by a break of at least one hour between watches and may conduct a maximum of 12 hours of observation per 24-hour period.

Combined observational duties (visual and acoustic but not at same time) may not exceed 12 hours per 24-hour period for any individual PSO.

(d) Acoustic Monitoring

(i) The source vessel must use a towed passive acoustic monitoring system (PAM) which must be monitored by, at a minimum, one on duty acoustic PSO beginning at least 30 minutes prior to ramp-up and at all times during use of the acoustic source.

(ii) When both visual and acoustic PSOs are on duty, all detections must be immediately communicated to the remainder of the on-duty PSO team for potential verification of visual observations by the acoustic PSO or of acoustic detections by visual PSOs.

(iii) Acoustic PSOs may be on watch for a maximum of four consecutive hours followed by a break of at least one hour between watches and may conduct a maximum of 12 hours of observation per 24-hour period. Combined observational duties may not exceed 12 hours per 24-hour period for any individual PSO.

(iv) Survey activity may continue for 30 minutes when the PAM system malfunctions or is damaged, while the PAM operator diagnoses the issue. If the diagnosis indicates that the PAM system must be repaired to solve the problem, operations may continue for an additional five hours without acoustic monitoring during daylight hours only under the following conditions:

a. Sea state is less than or equal to BSS 4;

b. With the exception of delphinids (other than killer whales), no marine mammals detected solely by PAM in the applicable exclusion zone in the previous two hours;

c. NMFS is notified via email as soon as practicable with the time and location in which operations began occurring without an active PAM system; and

d. Operations with an active acoustic source, but without an operating PAM system, do not exceed a cumulative total of five hours in any 24-hour period.

(e) Exclusion zone and buffer zone

(i) Except as provided below in 4(e)(ii), the PSOs must establish and monitor a 500-m exclusion zone and additional 500-m buffer zone (total 1,000 m).

The 1,000-m zone shall serve to focus observational effort but not limit such effort; observations of marine mammals beyond this distance shall also be recorded as described in 5(d) below and/or trigger shutdown as described in 4(g)(iv) below, as appropriate. The exclusion zone encompasses the area at and below the sea surface out to a radius of 500 m from the edges of the airgun array (rather than being based on the center of the array or around the vessel itself) (0–500 m). The buffer zone encompasses the area at and below the sea surface from the edge of the exclusion zone, out to a radius of 1,000 meters from the edges of the airgun array (500–1,000 m). During use of the acoustic source, occurrence of marine mammals within the buffer zone (but outside the exclusion zone) must be communicated to the operator to prepare for the potential shutdown of the acoustic source. PSOs must monitor the exclusion zone and buffer zone for a minimum of 30 minutes prior to ramp-up (*i.e.*, pre-start clearance).

(ii) An extended 1,500-m exclusion zone must be established for all beaked whales, and dwarf and pygmy sperm whales. No buffer zone is required.

(f) Pre-start clearance and Ramp-up

(i) A ramp-up procedure must be followed at all times as part of the activation of the acoustic source, except as described under 4(f)(vi).

(ii) Ramp-up must not be initiated if any marine mammal is within the exclusion or buffer zone. If a marine mammal is observed within the exclusion zone or the buffer zone during the 30 minute pre-start clearance period, ramp-up may not begin until the animal(s) has been observed exiting the zone or until an additional time period has elapsed with no further sightings (15 minutes for small odontocetes and pinnipeds, and 30 minutes for mysticetes and all other odontocetes, including sperm whales, pygmy sperm whales, dwarf sperm whales, beaked whales, pilot whales, killer whales, false killer whales, and Risso's dolphins).

(iii) Ramp-up must begin by activating a single airgun of the smallest volume in the array and must continue in stages by doubling the number of active elements at the commencement of each stage, with each stage of approximately the same duration. Duration must not be less than 20 minutes.

(iv) PSOs must monitor the exclusion and buffer zones during ramp-up, and ramp-up must cease and the source must be shut down upon visual observation or acoustic detection of a marine mammal within the exclusion zone. Once ramp-up has begun, observations of marine mammals within the buffer zone do not require shutdown, but such observation must be communicated to the operator to prepare for the potential shutdown.

(v) Ramp-up may occur at times of poor visibility, including nighttime, if appropriate acoustic monitoring has occurred with no detections in the 30 minutes prior to beginning ramp-up.

(vi) If the acoustic source is shut down for brief periods (*i.e.*, less than 30 minutes) for reasons other than that described for shutdown (*e.g.*, mechanical difficulty), it may be activated again without ramp-up if PSOs have maintained constant visual and/or acoustic observation and no visual or acoustic detections of marine mammals have occurred within the applicable exclusion zone. For any longer shutdown, pre-start clearance observation and ramp-up are required. For any shutdown at night or in periods of poor visibility (*e.g.*, BSS 4 or greater), ramp-up is required, but if the shutdown period was brief and constant observation was maintained, pre-start clearance watch is not required.

(vii) Testing of the acoustic source involving all elements requires ramp-up. Testing limited to individual source elements or strings does not require ramp-up but does require pre-start clearance watch.

(g) Shutdown

(i) Any PSO on duty has the authority to delay the start of survey operations or to call for shutdown of the acoustic source.

(ii) The operator must establish and maintain clear lines of communication directly between PSOs on duty and crew controlling the acoustic source to ensure that shutdown commands are conveyed swiftly while allowing PSOs to maintain watch.

(iii) When the airgun array is active (*i.e.*, anytime one or more airguns is active, including during ramp-up) and (1) a marine mammal (excluding delphinids of the genera described in 4(g)(v)) appears within or enters the exclusion zone and/or (2) a marine mammal is detected acoustically and localized within the exclusion zone, the acoustic source must be shut down. When shutdown is called for by a PSO, the airgun array must be immediately deactivated. Any dispute regarding a PSO shutdown must be resolved after deactivation.

(iv) The airgun array must be shut down if any of the following are detected at any distance:

1. North Pacific right whale.

2. Killer whale (of any ecotype).

3. Large whale (defined as a sperm whale or any mysticete species) with a calf (defined as an animal less than two-thirds the body size of an adult observed to be in close association with an adult).

4. Aggregation of six or more large whales.

(v) The shutdown requirements described in 4(g)(iii) shall be waived for small dolphins of the following genera: *Tursiops, Delphinus, Stenella, Lagenorhynchus,* and *Lissodelphis*.

a. If a small delphinid (individual of the Family Delphinidae, which includes the aforementioned dolphin genera), is visually and/or acoustically detected and localized within the exclusion zone, no shutdown is required unless the acoustic PSO or a visual PSO confirms the individual to be of a genera other than those listed above, in which case a shutdown is required.

b. If there is uncertainty regarding identification, visual PSOs may use best professional judgment in making the decision to call for a shutdown.

(vi) Upon implementation of shutdown, the source may be reactivated after the marine mammal(s) has been observed exiting the applicable exclusion zone (*i.e.*, animal is not required to fully exit the buffer zone where applicable) or following a clearance period (15 minutes for small odontocetes and pinnipeds, and 30 minutes for mysticetes and all other odontocetes, including sperm whales, pygmy sperm whales, dwarf sperm whales, beaked whales, pilot whales, killer whales, false killer whales, and Risso's dolphins) with no further observation of the marine mammal(s).

(h) Vessel operators and crews must maintain a vigilant watch for all marine mammals and slow down, stop their vessel, or alter course, as appropriate and regardless of vessel size, to avoid striking any marine mammal. A visual observer aboard the vessel must monitor a vessel strike avoidance zone around the vessel (specific distances detailed below). Visual observers monitoring the vessel strike avoidance zone may be third-party observers (*i.e.*, PSOs) or crew members, but crew members responsible for these duties must be provided sufficient training to 1) distinguish marine mammals from other phenomena and 2) broadly to identify a marine mammal as a right whale, other whale (defined in this context as sperm whales or baleen whales other than right whales), or other marine mammal.

(i) Vessel speeds must be reduced to 10 knots or less when mother/calf pairs, pods, or large assemblages of any marine mammal are observed near a vessel.

(ii) Vessels must maintain a minimum separation distance of 500 m from North Pacific right whales and 100 m from other large whales (*i.e*., sperm whales and all other baleen whales).

(iii) The vessel must, to the maximum extent practicable, attempt to maintain a minimum separation distance of 50 m from all other marine mammals, with an understanding that at times this may not be possible (*e.g*., for animals that approach the vessel).

(iv) When marine mammals are sighted while a vessel is underway, the vessel must take action as necessary to avoid violating the relevant separation distance (*e.g.*, attempt to remain parallel to the animal's course, avoid excessive speed or abrupt changes in direction until the animal has left the area). If marine mammals are sighted within the relevant separation distance, the vessel must reduce speed and shift the engine to neutral, not engaging the engines until animals are clear of the area. This does not apply to any vessel towing gear or any vessel that is navigationally constrained.

(v) These requirements do not apply in any case where compliance would create an imminent and serious threat to a person or vessel or to the extent that a vessel is restricted in its ability to maneuver and, because of the restriction, cannot comply.

(k) Survey operations in waters shallower than 200 m between Tillamook Head, Oregon (45.9460903° N) and Barkley Sound, British Columbia (48.780291° N), and survey operations within Olympic Coast National Marine Sanctuary, must be conducted in daylight hours only (*i.e.*, from 30 minutes prior to sunrise through 30 minutes following sunset).

(j) On each day of survey operations, L-DEO must contact NMFS Northwest Fisheries Science Center (206-860-3200), NMFS West Coast Regional Office (206-526-6150), The Whale Museum (800-562-8832), Orca Network (360-331-3543), Canada's Department of Fisheries and Oceans (604-666-9965), and Olympic Coast National Marine Sanctuary (208-410-0260), to obtain any available information regarding the whereabouts of Southern Resident killer whales.

5. Monitoring Requirements

The holder of this Authorization is required to conduct marine mammal monitoring during survey activity. Monitoring must be conducted in accordance with the following requirements:

(a) The operator must provide PSOs with bigeye binoculars (*e.g*., 25 x 150; 2.7 view angle; individual ocular focus; height control) of appropriate quality solely for

PSO use. These must be pedestal-mounted on the deck at the most appropriate vantage point that provides for optimal sea surface observation, PSO safety, and safe operation of the vessel.

(b) The operator must work with the selected third-party observer provider to ensure PSOs have all equipment (including backup equipment) needed to adequately perform necessary tasks, including accurate determination of distance and bearing to observed marine mammals. Such equipment, at a minimum, must include:

(i) PAM must include a system that has been verified and tested by an experienced acoustic PSO that will be using it during the trip for which monitoring is required.

(ii) Reticle binoculars (*e.g.*, 7 x 50) of appropriate quality (at least one per PSO, plus backups).

(iii) Global Positioning Unit (GPS) (plus backup).

(iv) Digital single-lens reflex cameras of appropriate quality that capture photographs and video (plus backup).

(v) Compass (plus backup).

(vi) Radios for communication among vessel crew and PSOs (at least one per PSO, plus backups).

(vii) Any other tools necessary to adequately perform necessary PSO tasks.

(c) Protected Species Observers (PSOs, Visual and Acoustic) Qualifications

(i) PSOs must have successfully completed an acceptable PSO training course appropriate for their designated task (visual or acoustic). Acoustic PSOs are required to complete specialized training for operating PAM systems and are encouraged to have familiarity with the vessel with which they will be working.

(ii) NMFS must review and approve PSO resumes.

(iii) NMFS shall have one week to approve PSOs from the time that the necessary information is submitted, after which PSOs meeting the minimum requirements shall automatically be considered approved.

(iv) One visual PSO with experience as shown in condition 4(b) of this authorization shall be designated as the lead for the entire protected species observation team. The lead must coordinate duty schedules and roles for the PSO team and serve as primary point of contact for the vessel operator. (Note that the responsibility of coordinating duty schedules and roles may instead be assigned to a shore-based, third-party monitoring coordinator.) To the maximum extent practicable, the lead PSO must devise the duty schedule such that experienced PSOs are on duty with those PSOs with appropriate training but who have not yet gained relevant experience.

(v) PSOs must successfully complete relevant training, including completion of all required coursework and passing (80 percent or greater) a written and/or oral examination developed for the training program.

(vi) PSOs must have successfully attained a bachelor's degree from an accredited college or university with a major in one of the natural sciences, a minimum of 30 semester hours or equivalent in the biological sciences, and at least one undergraduate course in math or statistics.

(vii) The educational requirements may be waived if the PSO has acquired the relevant skills through alternate experience. Requests for such a waiver must be submitted to NMFS and must include written justification. Requests must be granted or denied (with justification) by NMFS within one week of receipt of submitted information. Alternate experience that may be considered includes, but is not limited to (1) secondary education and/or experience comparable to PSO duties; (2) previous work experience conducting academic, commercial, or government-sponsored protected species surveys; or (3) previous work experience as a PSO; the PSO should demonstrate good standing and consistently good performance of PSO duties.

(d) Data Collection

(i) PSOs must use standardized data collection forms, whether hard copy or electronic. PSOs must record detailed information about any implementation of mitigation requirements, including the distance of animals to the acoustic source and description of specific actions that ensued, the behavior of the animal(s), any observed changes in behavior before and after implementation of mitigation, and if shutdown was implemented, the length of time before any subsequent ramp-up of the acoustic source. If required mitigation was not implemented, PSOs should record a description of the circumstances.

(ii) At a minimum, the following information must be recorded:

a. Vessel names (source vessel and other vessels associated with survey) and call signs;

b. PSO names and affiliations;

c. Date and participants of PSO briefings (as discussed in General Requirement);

d. Dates of departures and returns to port with port name;

e. Dates and times (Greenwich Mean Time) of survey effort and times corresponding with PSO effort;

f. Vessel location (latitude/longitude) when survey effort began and ended and vessel location at beginning and end of visual PSO duty shifts;

g. Vessel heading and speed at beginning and end of visual PSO duty shifts and upon any line change;

h. Environmental conditions while on visual survey (at beginning and end of PSO shift and whenever conditions changed significantly), including BSS and any other relevant weather conditions including cloud cover, fog, sun glare, and overall visibility to the horizon;

i. Factors that may have contributed to impaired observations during each PSO shift change or as needed as environmental conditions changed (*e.g.*, vessel traffic, equipment malfunctions); and

j. Survey activity information, such as acoustic source power output while in operation, number and volume of airguns operating in the array, tow depth of the array, and any other notes of significance (*i.e.*, pre-start clearance, ramp-up, shutdown, testing, shooting, ramp-up completion, end of operations, streamers, etc.).

(iii) Upon visual observation of any marine mammal, the following information must be recorded:

a. Watch status (sighting made by PSO on/off effort, opportunistic, crew, alternate vessel/platform);

b. PSO who sighted the animal;

c. Time of sighting;

d. Vessel location at time of sighting;

e. Water depth;

f. Direction of vessel's travel (compass direction);

g. Direction of animal's travel relative to the vessel;

h. Pace of the animal;

i. Estimated distance to the animal and its heading relative to vessel at initial sighting;

j. Identification of the animal (*e.g*., genus/species, lowest possible taxonomic level, or unidentified) and the composition of the group if there is a mix of species;

k. Estimated number of animals (high/low/best);

l. Estimated number of animals by cohort (adults, yearlings, juveniles, calves, group composition, etc.);

m. Description (as many distinguishing features as possible of each individual seen, including length, shape, color, pattern, scars or markings, shape and size of dorsal fin, shape of head, and blow characteristics);

n. Detailed behavior observations (*e.g*., number of blows/breaths, number of surfaces, breaching, spyhopping, diving, feeding, traveling; as explicit and detailed as possible; note any observed changes in behavior);

o. Animal's closest point of approach (CPA) and/or closest distance from any element of the acoustic source;

p. Platform activity at time of sighting (*e.g*., deploying, recovering, testing, shooting, data acquisition, other); and

q. Description of any actions implemented in response to the sighting (*e.g*., delays, shutdown, ramp-up) and time and location of the action.

(iv) If a marine mammal is detected while using the PAM system, the following information must be recorded:

a. An acoustic encounter identification number, and whether the detection was linked with a visual sighting;

b. Date and time when first and last heard;

c. Types and nature of sounds heard (*e.g*., clicks, whistles, creaks, burst pulses, continuous, sporadic, strength of signal);

d. Any additional information recorded such as water depth of the hydrophone array, bearing of the animal to the vessel (if determinable), species or taxonomic group (if determinable), spectrogram screenshot, and any other notable information.

6. Reporting

(a) L-DEO must submit a draft comprehensive report to NMFS on all activities and monitoring results within 90 days of the completion of the survey or expiration of the IHA, whichever comes sooner. A final report must be submitted within 30 days following resolution of any comments on the draft report. The draft report must include the following:

(i) Summary of all activities conducted and sightings of marine mammals near the activities;

(ii) Summary of all data required to be collected (see condition 5(d));

(iii) Full documentation of methods, results, and interpretation pertaining to all monitoring;

(iv) Summary of dates and locations of survey operations (including (1) the number of days on which the airgun array was active and (2) the percentage of time and total time the array was active during daylight vs. nighttime hours (including dawn and dusk)) and all marine mammal sightings (dates, times, locations, activities, associated survey activities);

(v) Geo-referenced time-stamped vessel tracklines for all time periods during which airguns were operating. Tracklines should include points recording any change in airgun status (*e.g*., when the airguns began operating, when they were turned off, or when they changed from full array to single gun or vice versa);

(vi) GIS files in ESRI shapefile format and UTC date and time, latitude in decimal degrees, and longitude in decimal degrees. All coordinates must be referenced to the WGS84 geographic coordinate system; and

(vii) Raw observational data.

(b) Reporting Injured or Dead Marine Mammals

(i) Discovery of Injured or Dead Marine Mammal – In the event that personnel involved in the survey activities covered by the authorization discover an injured or dead marine mammal, L-DEO must report the incident to the Office of Protected Resources (OPR) (301-427-8401), NMFS and the NMFS West Coast Regional Stranding Coordinator (866-767-6114) as soon as feasible. The report must include the following information:

a. Time, date, and location (latitude/longitude) of the first discovery (and updated location information if known and applicable);

b. Species identification (if known) or description of the animal(s) involved;

c. Condition of the animal(s) (including carcass condition if the animal is dead);

d. Observed behaviors of the animal(s), if alive;

e. If available, photographs or video footage of the animal(s); and

f. General circumstances under which the animal was discovered.

(ii) Vessel Strike – In the event of a ship strike of a marine mammal by any vessel involved in the activities covered by the authorization, L-DEO must report the incident to OPR, NMFS and to the West Coast Regional Stranding Coordinator as soon as feasible. The report must include the following information:

a. Time, date, and location (latitude/longitude) of the incident;

b. Species identification (if known) or description of the animal(s) involved;

c. Vessel's speed during and leading up to the incident;

d. Vessel's course/heading and what operations were being conducted (if applicable);

e. Status of all sound sources in use;

f. Description of avoidance measures/requirements that were in place at the time of the strike and what additional measures were taken, if any, to avoid strike;

g. Environmental conditions (*e.g.*, wind speed and direction, Beaufort sea state, cloud cover, visibility) immediately preceding the strike;

h. Estimated size and length of animal that was struck;

i. Description of the behavior of the marine mammal immediately preceding and following the strike;

j. If available, description of the presence and behavior of any other marine mammals immediately preceding the strike;

k. Estimated fate of the animal (*e.g.*, dead, injured but alive, injured and moving, blood or tissue observed in the water, status unknown, disappeared); and

l. To the extent practicable, photographs or video footage of the animal(s).

(c) Reporting Species of Concern – L-DEO must immediately report all observations of Southern Resident killer whales and North Pacific right whales to OPR, NMFS (301-427-8401). If Southern Resident killer whales or North Pacific right whales are observed within Olympic Coast National Marine Sanctuary, L-DEO must also immediately report the sightings to the Sanctuary (208-410-0260). The report must include the following information:

(i) Time, date, and location (latitude/longitude, water depth) of the observation;

(ii) Description of the animal(s) seen, including estimated number of animals, estimated age and sex classes observed, and distinguishing features;

(iii) Behavior observations (*e.g.*, number of blows/breaths, number of surfaces, breaching, spyhopping, diving, feeding, traveling; as explicit and detailed as possible);

(iv) Direction of vessel's travel (compass direction) and direction of animal's travel relative to the vessel; and

(v) Platform activity at time of sighting (*e.g.*, deploying, recovering, testing, shooting, data acquisition, other).

7. <u>Actions to minimize additional harm to live-stranded (or milling) marine mammals</u> – In the event of a live stranding (or near-shore atypical milling) event within 50 km of the survey operations, where the NMFS stranding network is engaged in herding or other interventions to return animals to the water, the Director of OPR, NMFS (or designee) will advise L-DEO of the need to implement shutdown procedures for all active acoustic sources operating within 50 km of the stranding. Shutdown procedures for live stranding or milling marine mammals include the following:

(a) If at any time, the marine mammal(s) die or are euthanized, or if herding/intervention efforts are stopped, the Director of OPR, NMFS (or designee) will advise L-DEO that the shutdown around the animals' location is no longer needed.

(b) Otherwise, shutdown procedures will remain in effect until the Director of OPR, NMFS (or designee) determines and advises L-DEO that all live animals involved have left the area (either of their own volition or following an intervention).

(c) If further observations of the marine mammals indicate the potential for re-stranding, additional coordination with L-DEO will be required to determine what measures are necessary to minimize that likelihood (*e.g.*, extending the shutdown or moving operations farther away) and to implement those measures as appropriate.

(d) Additional information requests – If NMFS determines that the circumstances of any marine mammal stranding found in the vicinity of the activity suggest investigation of the association with survey activities is warranted, and an investigation into the stranding is being pursued, NMFS will submit a written request to L-DEO indicating that the following initial available information must be provided as soon as possible, but no later than 7 business days after the request for information.

(i) Status of all sound source use in the 48 hours preceding the estimated time of stranding and within 50 km of the discovery/notification of the stranding by NMFS; and

(ii) If available, description of the behavior of any marine mammal(s) observed preceding (*i.e.*, within 48 hours and 50 km) and immediately after the discovery of the stranding.

In the event that the investigation is still inconclusive, the investigation of the association of the survey activities is still warranted, and the investigation is still being pursued, NMFS may provide additional information requests, in writing, regarding the nature and location of survey operations prior to the time period above.

8. This Authorization may be modified, suspended or withdrawn if the holder fails to abide by the conditions prescribed herein, or if NMFS determines the authorized taking is having more than a negligible impact on the species or stock of affected marine mammals.

9. Renewals - On a case-by-case basis, NMFS may issue a one-time, one-year Renewal IHA following notice to the public providing an additional 15 days for public comments when (1) up to another year of identical, or nearly identical, activities as described in the Specified Activities section of this notice is planned or (2) the activities as described in

the Specified Activities section of this notice would not be completed by the time the IHA expires and a Renewal would allow for completion of the activities beyond that described in the Dates and Duration section of this notice, provided all of the following conditions are met:

(a) A request for renewal is received no later than 60 days prior to the needed Renewal IHA effective date (recognizing that the Renewal IHA expiration date cannot extend beyond one year from expiration of the initial IHA).

(b) The request for renewal must include the following:

(i) An explanation that the activities to be conducted under the requested Renewal IHA are identical to the activities analyzed under the initial IHA, are a subset of the activities, or include changes so minor (*e.g.*, reduction in pile size) that the changes do not affect the previous analyses, mitigation and monitoring requirements, or take estimates (with the exception of reducing the type or amount of take).

(ii) A preliminary monitoring report showing the results of the required monitoring to date and an explanation showing that the monitoring results do not indicate impacts of a scale or nature not previously analyzed or authorized.

(c) Upon review of the request for Renewal, the status of the affected species or stocks, and any other pertinent information, NMFS determines that there are no more than minor changes in the activities, the mitigation and monitoring measures will remain the same and appropriate, and the findings in the initial IHA remain valid.

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Catherine Marzin, Date
Acting Director, Office of Protected Resources,
National Marine Fisheries Service.

Table 1. Numbers of Incidental Take of Marine Mammals Authorized.

Species	MMPA Stock	Authorized Take		Total Authorized Take
		Level B	Level A	
LF Cetaceans				
Humpback whale	Central North Pacific California/Oregon/Washington	112	29	141
Blue whale	Eastern North Pacific	40	11	51
Fin whale	California/Oregon/Washington Northeast Pacific	94	1	95
Sei whale	Eastern North Pacific	30	2	32
Minke whale	California/Oregon/Washington	96	7	103
Gray whale	Eastern North Pacific	43	1	44
MF Cetaceans				
Sperm whale	California/Oregon/Washington	72	0	72
Baird's beaked whale	California/Oregon/Washington	84	0	84
Small beaked whale	California/Oregon/Washington	242	0	242
Bottlenose dolphin	California/Oregon/Washington (offshore)	13	0	13
Striped dolphin	California/Oregon/Washington	46	0	46
Short-beaked common dolphin	California/Oregon/Washington	179	0	179
Pacific white-sided dolphin	California/Oregon/Washington	6084	0	6084

Northern right-whale dolphin	California/Oregon/Washington	4318	0	4318
Risso's dolphin	California/Oregon/Washington	1664	0	1664
False killer whale	Hawai'i Pelagic	5	0	5
Killer whale	Southern Resident	10	0	10
	Northern Resident West Coast Transient Offshore	73	0	73
Short-finned pilot whale	California/Oregon/Washington	29	0	29
HF Cetaceans				
Pygmy/dwarf sperm whale	California/Oregon/Washington	125	5	130
Dall's porpoise	California/Oregon/Washington	9762	488	10250
Harbor porpoise	Northern Oregon/Washington Coast Northern California/Southern Oregon	7958	283	8241
Otariid Seals				
Northern fur seal	Eastern Pacific California	4592	0	4592
Guadalupe fur seal	Mexico to California	2048	0	2048
California sea lion	U.S.	889	0	889
Steller sea lion	Eastern U.S.	7504	0	7504
Phocid Seals				
Northern elephant seal	California Breeding	2754	0	2754
Harbor seal	Oregon/Washington Coast	3887	0	3887

Table 2. Level B Harassment Zones by Water Depth

Water depth (m)	Level B harassment zone (m)
> 1000	6,733
100 – 1000	9,468
< 100	12,650

Table 3. Level A Harassment Zones by Hearing Group

Source (volume)	Threshold	Level A harassment zone (m)				
		LF cetaceans	MF cetaceans	HF cetaceans	Phocids	Otariids
36-airgun array (6,600 in^3)	SEL_{cum}	426.9	0	1.3	13.9	0
	Peak	38.9	13.6	268.3	43.7	10.6

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
1315 East-West Highway
Silver Spring, Maryland 20910

INCIDENTAL HARASSMENT AUTHORIZATION

The Lamont-Doherty Earth Observatory of Columbia University (L-DEO) is hereby authorized under section 101(a)(5)(D) of the Marine Mammal Protection Act (MMPA; 16 U.S.C. 1371(a)(5)(D)) to harass marine mammals incidental to a geophysical survey in the Northeast Pacific Ocean, when adhering to the following terms and conditions.

1. This Incidental Harassment Authorization (IHA) is valid for a period of one year from the date of issuance.

2. This IHA is valid only for geophysical survey activity as specified in L-DEO's IHA application and using an array aboard the R/V *Langseth* with characteristics specified in the IHA application, in the Northeast Pacific Ocean along the Cascadia Subduction Zone.

3. General Conditions

   (a) A copy of this IHA must be in the possession of L-DEO, the vessel operator, the lead protected species observer (PSO) and any other relevant designees of L-DEO operating under the authority of this IHA.

   (b) The species authorized for taking are listed in Table 1. The taking, by Level A and Level B harassment only, is limited to the species and numbers listed in Table 1.

   (c) The taking by serious injury or death of any of the species listed in Table 1 or any taking of any other species of marine mammal is prohibited and may result in the modification, suspension, or revocation of this IHA. Any taking exceeding the authorized amounts listed in Table 1 is prohibited and may result in the modification, suspension, or revocation of this IHA.

   (d) During use of the acoustic source, if any marine mammal species that are not listed in Table 1 appear within or enter the Level B harassment zone (Table 2) or a species for which authorization has been granted but the takes have been met, is observed within or approaching the Level A or Level B harassment zones (Tables 2-3), the acoustic source must be shut down.

   (e) L-DEO must ensure that relevant vessel personnel and PSO team participate in a joint onboard briefing led by the vessel operator and lead PSO to ensure that responsibilities, communication procedures, protected species monitoring protocols, operational procedures, and IHA requirements are clearly understood.

4. Mitigation Measures

   The holder of this Authorization is required to implement the following mitigation measures:

(a) L-DEO must use independent, dedicated, trained visual and acoustic PSOs, meaning that the PSOs must be employed by a third-party observer provider, must not have tasks other than to conduct observational effort, collect data, and communicate with and instruct relevant vessel crew with regard to the presence of protected species and mitigation requirements (including brief alerts regarding maritime hazards), and must have successfully completed an approved PSO training course appropriate for their designated task (visual or acoustic). Individual PSOs may perform acoustic and visual PSO duties (though not at the same time).

(b) At least one visual and two acoustic PSOs aboard the R/V *Langseth* and at least one visual PSO aboard the second vessel (see condition 4(c)(iii)) must have a minimum of 90 days at-sea experience working in those roles, respectively, during a deep penetration seismic survey, with no more than 18 months elapsed since the conclusion of the at-sea experience.

(c) Visual Observation

(i) During survey operations *(e.g.*, any day on which use of the acoustic source is planned to occur, and whenever the acoustic source is in the water, whether activated or not), a minimum of two PSOs must be on duty and conducting visual observations at all times during daylight hours (*i.e.*, from 30 minutes prior to sunrise through 30 minutes following sunset) and 30 minutes prior to and during ramp-up of the airgun array. Visual monitoring of the exclusion and buffer zones must begin no less than 30 minutes prior to ramp-up and must continue until one hour after use of the acoustic source ceases or until 30 minutes past sunset.

(ii) Visual PSOs must coordinate to ensure 360° visual coverage around the vessel from the most appropriate observation posts, and must conduct visual observations using binoculars and the naked eye while free from distractions and in a consistent, systematic, and diligent manner. Estimated harassment zones are provided in Tables 2-3 for reference.

(iii) During survey operations in water depths shallower than 200 m between Tillamook Head, Oregon (45.9460903° N) and Barkley Sound, British Columbia (48.780291° N), and while surveying within Olympic Coast National Marine Sanctuary, a second vessel with additional visual PSOs must accompany the R/V *Langseth* and survey approximately 5 km ahead of the R/V *Langseth*. Two visual PSOs must be on watch on the second vessel during all such survey operations (according to the requirements provided in 4(c)(i) of this IHA) and communicate all observations of marine mammals to PSOs on the R/V *Langseth*.

(iv) Visual PSOs must immediately communicate all observations to the acoustic PSO(s) on duty, including any determination by the PSO regarding species identification, distance, and bearing and the degree of confidence in the determination.

(v) During good conditions (*e.g.*, daylight hours; Beaufort sea state (BSS) 3 or less), visual PSOs must conduct observations when the acoustic source is not operating for comparison of sighting rates and behavior with and without use of the acoustic source and between acquisition periods, to the maximum extent practicable.

(vi) Visual PSOs may be on watch for a maximum of four consecutive hours followed by a break of at least one hour between watches and may conduct a maximum of 12 hours of observation per 24-hour period. Combined observational duties (visual and acoustic but not at same time) may not exceed 12 hours per 24-hour period for any individual PSO.

(d) Acoustic Monitoring

(i) The source vessel must use a towed passive acoustic monitoring system (PAM) which must be monitored by, at a minimum, one on duty acoustic PSO beginning at least 30 minutes prior to ramp-up and at all times during use of the acoustic source.

(ii) When both visual and acoustic PSOs are on duty, all detections must be immediately communicated to the remainder of the on-duty PSO team for potential verification of visual observations by the acoustic PSO or of acoustic detections by visual PSOs.

(iii) Acoustic PSOs may be on watch for a maximum of four consecutive hours followed by a break of at least one hour between watches and may conduct a maximum of 12 hours of observation per 24-hour period. Combined observational duties may not exceed 12 hours per 24-hour period for any individual PSO.

(iv) Survey activity may continue for 30 minutes when the PAM system malfunctions or is damaged, while the PAM operator diagnoses the issue. If the diagnosis indicates that the PAM system must be repaired to solve the problem, operations may continue for an additional five hours without acoustic monitoring during daylight hours only under the following conditions:

a. Sea state is less than or equal to BSS 4;

b. With the exception of delphinids (other than killer whales), no marine mammals detected solely by PAM in the applicable exclusion zone in the previous two hours;

c. NMFS is notified via email as soon as practicable with the time and location in which operations began occurring without an active PAM system; and

d. Operations with an active acoustic source, but without an operating PAM system, do not exceed a cumulative total of five hours in any 24-hour period.

(e) Exclusion zone and buffer zone

(i) Except as provided below in 4(e)(ii), the PSOs must establish and monitor a 500-m exclusion zone and additional 500-m buffer zone (total 1,000 m). The 1,000-m zone shall serve to focus observational effort but not limit such effort; observations of marine mammals beyond this distance shall also be recorded as described in 5(d) below and/or trigger shutdown as described in 4(g)(iv) below, as appropriate. The exclusion zone encompasses the area at and below the sea surface out to a radius of 500 m from the edges of the airgun array (rather than being based on the center of the array or around the vessel itself) (0–500 m). The buffer zone encompasses the area at and below the sea surface from the edge of the exclusion zone, out to a radius of 1,000 meters from the edges of the airgun array (500–1,000 m). During use of the acoustic source, occurrence of marine mammals within the buffer zone (but outside the exclusion zone) must be communicated to the operator to prepare for the potential shutdown of the acoustic source. PSOs must monitor the exclusion zone and buffer zone for a minimum of 30 minutes prior to ramp-up (*i.e.*, pre-start clearance).

(ii) An extended 1,500-m exclusion zone must be established for all beaked whales, and dwarf and pygmy sperm whales. No buffer zone is required.

(f) Pre-start clearance and Ramp-up

(i) A ramp-up procedure must be followed at all times as part of the activation of the acoustic source, except as described under 4(f)(vi).

(ii) Ramp-up must not be initiated if any marine mammal is within the exclusion or buffer zone. If a marine mammal is observed within the exclusion zone or the buffer zone during the 30 minute pre-start clearance period, ramp-up may not begin until the animal(s) has been observed exiting the zone or until an additional time period has elapsed with no further sightings (15 minutes for small odontocetes and pinnipeds, and 30 minutes for mysticetes and all other odontocetes, including sperm whales, pygmy sperm whales, dwarf sperm whales, beaked whales, pilot whales, killer whales, false killer whales, and Risso’s dolphins).

(iii) Ramp-up must begin by activating a single airgun of the smallest volume in the array and must continue in stages by doubling the number of active elements at the commencement of each stage, with each stage of approximately the same duration. Duration must not be less than 20 minutes.

(iv) PSOs must monitor the exclusion and buffer zones during ramp-up, and ramp-up must cease and the source must be shut down upon visual observation or acoustic detection of a marine mammal within the exclusion zone. Once ramp-up has begun, observations of marine mammals within the buffer zone do not require shutdown, but such observation must be communicated to the operator to prepare for the potential shutdown.

(v) Ramp-up may occur at times of poor visibility, including nighttime, if appropriate acoustic monitoring has occurred with no detections in the 30 minutes prior to beginning ramp-up.

(vi) If the acoustic source is shut down for brief periods (*i.e.*, less than 30 minutes) for reasons other than that described for shutdown (*e.g.*, mechanical difficulty), it may be activated again without ramp-up if PSOs have maintained constant visual and/or acoustic observation and no visual or acoustic detections of marine mammals have occurred within the applicable exclusion zone. For any longer shutdown, pre-start clearance observation and ramp-up are required. For any shutdown at night or in periods of poor visibility (*e.g.*, BSS 4 or greater), ramp-up is required, but if the shutdown period was brief and constant observation was maintained, pre-start clearance watch is not required.

(vii) Testing of the acoustic source involving all elements requires ramp-up. Testing limited to individual source elements or strings does not require ramp-up but does require pre-start clearance watch.

(g) Shutdown

(i) Any PSO on duty has the authority to delay the start of survey operations or to call for shutdown of the acoustic source.

(ii) The operator must establish and maintain clear lines of communication directly between PSOs on duty and crew controlling the acoustic source to ensure that shutdown commands are conveyed swiftly while allowing PSOs to maintain watch.

(iii) When the airgun array is active (*i.e.*, anytime one or more airguns is active, including during ramp-up) and (1) a marine mammal (excluding delphinids of the genera described in 4(g)(v)) appears within or enters the exclusion zone and/or (2) a marine mammal is detected acoustically and localized within the exclusion zone, the acoustic source must be shut down. When shutdown is called for by a PSO, the airgun array must be immediately deactivated. Any dispute regarding a PSO shutdown must be resolved after deactivation.

(iv) The airgun array must be shut down if any of the following are detected at any distance:

a. North Pacific right whale.

b. Killer whale (of any ecotype).

c. Large whale (defined as a sperm whale or any mysticete species) with a calf (defined as an animal less than two-thirds the body size of an adult observed to be in close association with an adult).

d. Aggregation of six or more large whales.

(v) The shutdown requirements described in 4(g)(iii) shall be waived for small dolphins of the following genera: *Tursiops, Delphinus, Stenella, Lagenorhynchus,* and *Lissodelphis*.

a. If a small delphinid (individual of the Family Delphinidae, which includes the aforementioned dolphin genera), is visually and/or acoustically detected and localized within the exclusion zone, no shutdown is required unless the acoustic PSO or a visual PSO confirms the individual to be of a genera other than those listed above, in which case a shutdown is required.

b. If there is uncertainty regarding identification, visual PSOs may use best professional judgment in making the decision to call for a shutdown.

(vi) Upon implementation of shutdown, the source may be reactivated after the marine mammal(s) has been observed exiting the applicable exclusion zone (*i.e*., animal is not required to fully exit the buffer zone where applicable) or following a clearance period (15 minutes for small odontocetes and pinnipeds, and 30 minutes for mysticetes and all other odontocetes, including sperm whales, pygmy sperm whales, dwarf sperm whales, beaked whales, pilot whales, killer whales, false killer whales, and Risso's dolphins) with no further observation of the marine mammal(s).

(h) Vessel operators and crews must maintain a vigilant watch for all marine mammals and slow down, stop their vessel, or alter course, as appropriate and regardless of vessel size, to avoid striking any marine mammal. A visual observer aboard the vessel must monitor a vessel strike avoidance zone around the vessel (specific distances detailed below). Visual observers monitoring the vessel strike avoidance zone may be third-party observers (*i.e.*, PSOs) or crew members, but crew members responsible for these duties must be provided sufficient training to 1) distinguish marine mammals from other phenomena and 2) broadly to identify a marine mammal as a right whale, other whale (defined in this context as sperm whales or baleen whales other than right whales), or other marine mammal.

(i) Vessel speeds must be reduced to 10 knots or less when mother/calf pairs, pods, or large assemblages of any marine mammal are observed near a vessel.

(ii) Vessels must maintain a minimum separation distance of 500 m from North Pacific right whales and 100 m from other large whales (*i.e.*, sperm whales and all other baleen whales).

(iii) The vessel must, to the maximum extent practicable, attempt to maintain a minimum separation distance of 50 m from all other marine mammals, with an understanding that at times this may not be possible (*e.g.*, for animals that approach the vessel).

(iv) When marine mammals are sighted while a vessel is underway, the vessel must take action as necessary to avoid violating the relevant separation distance (*e.g.*, attempt to remain parallel to the animal's course, avoid excessive speed or abrupt changes in direction until the animal has left the area). If marine mammals are sighted within the relevant separation distance, the vessel must reduce speed and shift the engine to neutral, not engaging the engines until animals are clear of the area. This does not apply to any vessel towing gear or any vessel that is navigationally constrained.

(v) These requirements do not apply in any case where compliance would create an imminent and serious threat to a person or vessel or to the extent that a vessel is restricted in its ability to maneuver and, because of the restriction, cannot comply.

(i) Survey operations in waters shallower than 200 m between Tillamook Head, Oregon (45.9460903° N) and Barkley Sound, British Columbia (48.780291° N), and survey operations within Olympic Coast National Marine Sanctuary, must be conducted in daylight hours only (*i.e.*, from 30 minutes prior to sunrise through 30 minutes following sunset).

(j) On each day of survey operations, L-DEO must contact NMFS Northwest Fisheries Science Center (206-860-3200), NMFS West Coast Regional Office (206-526-6150), The Whale Museum (800-562-8832), Orca Network (360-331-3543), Canada's Department of Fisheries and Oceans (604-666-9965), and Olympic Coast National Marine Sanctuary (208-410-0260), to obtain any available information regarding the whereabouts of Southern Resident killer whales.

5. Monitoring Requirements

The holder of this Authorization is required to conduct marine mammal monitoring during survey activity. Monitoring must be conducted in accordance with the following requirements:

(a) The operator must provide PSOs with bigeye binoculars (*e.g.*, 25 x 150; 2.7 view angle; individual ocular focus; height control) of appropriate quality solely for PSO use. These must be pedestal-mounted on the deck at the most appropriate vantage point that provides for optimal sea surface observation, PSO safety, and safe operation of the vessel.

(b) The operator must work with the selected third-party observer provider to ensure PSOs have all equipment (including backup equipment) needed to adequately perform necessary tasks, including accurate determination of distance and bearing to observed marine mammals. Such equipment, at a minimum, must include:

   (i) PAM must include a system that has been verified and tested by an experienced acoustic PSO that will be using it during the trip for which monitoring is required.

   (ii) Reticle binoculars (*e.g.*, 7 x 50) of appropriate quality (at least one per PSO, plus backups).

   (iii) Global Positioning Unit (GPS) (plus backup).

   (iv) Digital single-lens reflex cameras of appropriate quality that capture photographs and video (plus backup).

   (v) Compass (plus backup).

   (vi) Radios for communication among vessel crew and PSOs (at least one per PSO, plus backups).

   (vii) Any other tools necessary to adequately perform necessary PSO tasks.

(c) Protected Species Observers (PSOs, Visual and Acoustic) Qualifications

   (i) PSOs must have successfully completed an acceptable PSO training course appropriate for their designated task (visual or acoustic). Acoustic PSOs are required to complete specialized training for operating PAM systems and are encouraged to have familiarity with the vessel with which they will be working.

   (ii) NMFS must review and approve PSO resumes.

(iii) NMFS shall have one week to approve PSOs from the time that the necessary information is submitted, after which PSOs meeting the minimum requirements shall automatically be considered approved.

(iv) One visual PSO with experience as shown in condition 4(b) of this authorization shall be designated as the lead for the entire protected species observation team. The lead must coordinate duty schedules and roles for the PSO team and serve as primary point of contact for the vessel operator. (Note that the responsibility of coordinating duty schedules and roles may instead be assigned to a shore-based, third-party monitoring coordinator.) To the maximum extent practicable, the lead PSO must devise the duty schedule such that experienced PSOs are on duty with those PSOs with appropriate training but who have not yet gained relevant experience.

(v) PSOs must successfully complete relevant training, including completion of all required coursework and passing (80 percent or greater) a written and/or oral examination developed for the training program.

(vi) PSOs must have successfully attained a bachelor’s degree from an accredited college or university with a major in one of the natural sciences, a minimum of 30 semester hours or equivalent in the biological sciences, and at least one undergraduate course in math or statistics.

(vii) The educational requirements may be waived if the PSO has acquired the relevant skills through alternate experience. Requests for such a waiver must be submitted to NMFS and must include written justification. Requests must be granted or denied (with justification) by NMFS within one week of receipt of submitted information. Alternate experience that may be considered includes, but is not limited to (1) secondary education and/or experience comparable to PSO duties; (2) previous work experience conducting academic, commercial, or government-sponsored protected species surveys; or (3) previous work experience as a PSO; the PSO should demonstrate good standing and consistently good performance of PSO duties.

(d) Data Collection

(i) PSOs must use standardized data collection forms, whether hard copy or electronic. PSOs must record detailed information about any implementation of mitigation requirements, including the distance of animals to the acoustic source and description of specific actions that ensued, the behavior of the animal(s), any observed changes in behavior before and after implementation of mitigation, and if shutdown was implemented, the length of time before any subsequent ramp-up of the acoustic source. If required mitigation was not implemented, PSOs should record a description of the circumstances.

(ii) At a minimum, the following information must be recorded:

a. Vessel names (source vessel and other vessels associated with survey) and call signs;

b. PSO names and affiliations;

c. Date and participants of PSO briefings (as discussed in General Requirement);

d. Dates of departures and returns to port with port name;

e. Dates and times (Greenwich Mean Time) of survey effort and times corresponding with PSO effort;

f. Vessel location (latitude/longitude) when survey effort began and ended and vessel location at beginning and end of visual PSO duty shifts;

g. Vessel heading and speed at beginning and end of visual PSO duty shifts and upon any line change;

h. Environmental conditions while on visual survey (at beginning and end of PSO shift and whenever conditions changed significantly), including BSS and any other relevant weather conditions including cloud cover, fog, sun glare, and overall visibility to the horizon;

i. Factors that may have contributed to impaired observations during each PSO shift change or as needed as environmental conditions changed (*e.g.*, vessel traffic, equipment malfunctions); and

j. Survey activity information, such as acoustic source power output while in operation, number and volume of airguns operating in the array, tow depth of the array, and any other notes of significance (*i.e.*, pre-start clearance, ramp-up, shutdown, testing, shooting, ramp-up completion, end of operations, streamers, etc.).

(iii) Upon visual observation of any marine mammal, the following information must be recorded:

a. Watch status (sighting made by PSO on/off effort, opportunistic, crew, alternate vessel/platform);

b. PSO who sighted the animal;

c. Time of sighting;

d. Vessel location at time of sighting;

e. Water depth;

f. Direction of vessel's travel (compass direction);

g. Direction of animal's travel relative to the vessel;

h. Pace of the animal;

i. Estimated distance to the animal and its heading relative to vessel at initial sighting;

j. Identification of the animal (*e.g.*, genus/species, lowest possible taxonomic level, or unidentified) and the composition of the group if there is a mix of species;

k. Estimated number of animals (high/low/best);

l. Estimated number of animals by cohort (adults, yearlings, juveniles, calves, group composition, etc.);

m. Description (as many distinguishing features as possible of each individual seen, including length, shape, color, pattern, scars or markings, shape and size of dorsal fin, shape of head, and blow characteristics);

n. Detailed behavior observations (*e.g.*, number of blows/breaths, number of surfaces, breaching, spyhopping, diving, feeding, traveling; as explicit and detailed as possible; note any observed changes in behavior);

o. Animal's closest point of approach (CPA) and/or closest distance from any element of the acoustic source;

p. Platform activity at time of sighting (*e.g.*, deploying, recovering, testing, shooting, data acquisition, other); and

q. Description of any actions implemented in response to the sighting (*e.g.*, delays, shutdown, ramp-up) and time and location of the action.

(iv) If a marine mammal is detected while using the PAM system, the following information must be recorded:

a. An acoustic encounter identification number, and whether the detection was linked with a visual sighting;

b. Date and time when first and last heard;

c. Types and nature of sounds heard (*e.g.*, clicks, whistles, creaks, burst pulses, continuous, sporadic, strength of signal);

d. Any additional information recorded such as water depth of the hydrophone array, bearing of the animal to the vessel (if determinable), species or taxonomic group (if determinable), spectrogram screenshot, and any other notable information.

6. Reporting

(a) L-DEO must submit a draft comprehensive report to NMFS on all activities and monitoring results within 90 days of the completion of the survey or expiration of the IHA, whichever comes sooner. A final report must be submitted within 30 days following resolution of any comments on the draft report. The draft report must include the following:

(i) Summary of all activities conducted and sightings of marine mammals near the activities;

(ii) Summary of all data required to be collected (see condition 5(d));

(iii) Full documentation of methods, results, and interpretation pertaining to all monitoring;

(iv) Summary of dates and locations of survey operations (including (1) the number of days on which the airgun array was active and (2) the percentage of time and total time the array was active during daylight vs. nighttime hours (including dawn and dusk)) and all marine mammal sightings (dates, times, locations, activities, associated survey activities);

(v) Geo-referenced time-stamped vessel tracklines for all time periods during which airguns were operating. Tracklines should include points recording any change in airgun status (*e.g.*, when the airguns began operating, when they were turned off, or when they changed from full array to single gun or vice versa);

(vi) GIS files in ESRI shapefile format and UTC date and time, latitude in decimal degrees, and longitude in decimal degrees. All coordinates must be referenced to the WGS84 geographic coordinate system; and

(vii) Raw observational data.

(b) Reporting Injured or Dead Marine Mammals

(i) Discovery of Injured or Dead Marine Mammal – In the event that personnel involved in the survey activities covered by the authorization discover an injured or dead marine mammal, L-DEO must report the incident to the Office of Protected Resources (OPR) (301-427-8401), NMFS and the NMFS West Coast Regional Stranding Coordinator (866-767-6114) as soon as feasible. The report must include the following information:

a. Time, date, and location (latitude/longitude) of the first discovery (and updated location information if known and applicable);

b. Species identification (if known) or description of the animal(s) involved;

c. Condition of the animal(s) (including carcass condition if the animal is dead);

d. Observed behaviors of the animal(s), if alive;

e. If available, photographs or video footage of the animal(s); and

f. General circumstances under which the animal was discovered.

(ii) Vessel Strike – In the event of a ship strike of a marine mammal by any vessel involved in the activities covered by the authorization, L-DEO must report the incident to OPR, NMFS and to the West Coast Regional Stranding Coordinator as soon as feasible. The report must include the following information:

a. Time, date, and location (latitude/longitude) of the incident;

b. Species identification (if known) or description of the animal(s) involved;

c. Vessel's speed during and leading up to the incident;

d. Vessel's course/heading and what operations were being conducted (if applicable);

e. Status of all sound sources in use;

f. Description of avoidance measures/requirements that were in place at the time of the strike and what additional measures were taken, if any, to avoid strike;

g. Environmental conditions (*e.g.*, wind speed and direction, Beaufort sea state, cloud cover, visibility) immediately preceding the strike;

h. Estimated size and length of animal that was struck;

i. Description of the behavior of the marine mammal immediately preceding and following the strike;

j. If available, description of the presence and behavior of any other marine mammals immediately preceding the strike;

k. Estimated fate of the animal (*e.g.*, dead, injured but alive, injured and moving, blood or tissue observed in the water, status unknown, disappeared); and

l. To the extent practicable, photographs or video footage of the animal(s).

(c) Reporting Species of Concern – L-DEO must immediately report all observations of Southern Resident killer whales and North Pacific right whales to OPR, NMFS (301-427-8401). If Southern Resident killer whales or North Pacific right whales are observed within Olympic Coast National Marine Sanctuary, L-DEO must also immediately report the sightings to the Sanctuary (208-410-0260). The report must include the following information:

(i) Time, date, and location (latitude/longitude, water depth) of the observation;

(ii) Description of the animal(s) seen, including estimated number of animals, estimated age and sex classes observed, and distinguishing features;

(iii) Behavior observations (*e.g.*, number of blows/breaths, number of surfaces, breaching, spyhopping, diving, feeding, traveling; as explicit and detailed as possible);

(iv) Direction of vessel's travel (compass direction) and direction of animal's travel relative to the vessel; and

(v) Platform activity at time of sighting (*e.g.*, deploying, recovering, testing, shooting, data acquisition, other).

7. <u>Actions to minimize additional harm to live-stranded (or milling) marine mammals</u> – In the event of a live stranding (or near-shore atypical milling) event within 50 km of the survey operations, where the NMFS stranding network is engaged in herding or other interventions to return animals to the water, the Director of OPR, NMFS (or designee) will advise L-DEO of the need to implement shutdown procedures for all active acoustic

sources operating within 50 km of the stranding. Shutdown procedures for live stranding or milling marine mammals include the following:

(a) If at any time, the marine mammal(s) die or are euthanized, or if herding/intervention efforts are stopped, the Director of OPR, NMFS (or designee) will advise L-DEO that the shutdown around the animals' location is no longer needed.

(b) Otherwise, shutdown procedures will remain in effect until the Director of OPR, NMFS (or designee) determines and advises L-DEO that all live animals involved have left the area (either of their own volition or following an intervention).

(c) If further observations of the marine mammals indicate the potential for re-stranding, additional coordination with L-DEO will be required to determine what measures are necessary to minimize that likelihood (*e.g.*, extending the shutdown or moving operations farther away) and to implement those measures as appropriate.

(d) Additional information requests – If NMFS determines that the circumstances of any marine mammal stranding found in the vicinity of the activity suggest investigation of the association with survey activities is warranted, and an investigation into the stranding is being pursued, NMFS will submit a written request to L-DEO indicating that the following initial available information must be provided as soon as possible, but no later than 7 business days after the request for information.

(i) Status of all sound source use in the 48 hours preceding the estimated time of stranding and within 50 km of the discovery/notification of the stranding by NMFS; and

(ii) If available, description of the behavior of any marine mammal(s) observed preceding (*i.e.*, within 48 hours and 50 km) and immediately after the discovery of the stranding.

In the event that the investigation is still inconclusive, the investigation of the association of the survey activities is still warranted, and the investigation is still being pursued, NMFS may provide additional information requests, in writing, regarding the nature and location of survey operations prior to the time period above.

8. This Authorization may be modified, suspended or withdrawn if the holder fails to abide by the conditions prescribed herein, or if NMFS determines the authorized taking is having more than a negligible impact on the species or stock of affected marine mammals.

9. Renewals - On a case-by-case basis, NMFS may issue a one-time, one-year Renewal IHA following notice to the public providing an additional 15 days for public comments when

(1) up to another year of identical, or nearly identical, activities as described in the Specified Activities section of this notice is planned or (2) the activities as described in the Specified Activities section of this notice would not be completed by the time the IHA expires and a Renewal would allow for completion of the activities beyond that described in the Dates and Duration section of this notice, provided all of the following conditions are met:

(a) A request for renewal is received no later than 60 days prior to the needed Renewal IHA effective date (recognizing that the Renewal IHA expiration date cannot extend beyond one year from expiration of the initial IHA).

(b) The request for renewal must include the following:

(i) An explanation that the activities to be conducted under the requested Renewal IHA are identical to the activities analyzed under the initial IHA, are a subset of the activities, or include changes so minor (*e.g.*, reduction in pile size) that the changes do not affect the previous analyses, mitigation and monitoring requirements, or take estimates (with the exception of reducing the type or amount of take).

(ii) A preliminary monitoring report showing the results of the required monitoring to date and an explanation showing that the monitoring results do not indicate impacts of a scale or nature not previously analyzed or authorized.

(c) Upon review of the request for Renewal, the status of the affected species or stocks, and any other pertinent information, NMFS determines that there are no more than minor changes in the activities, the mitigation and monitoring measures will remain the same and appropriate, and the findings in the initial IHA remain valid.

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Catherine Marzin, Date
Acting Director, Office of Protected Resources,
National Marine Fisheries Service.

Table 1. Numbers of Incidental Take of Marine Mammals Authorized.

Species	MMPA Stock	Authorized Take		Total Authorized Take
		Level B	Level A	
LF Cetaceans				
Humpback whale	Central North Pacific California/Oregon/Washington	112	29	141
Blue whale	Eastern North Pacific	40	11	51
Fin whale	California/Oregon/Washington Northeast Pacific	94	1	95
Sei whale	Eastern North Pacific	30	2	32
Minke whale	California/Oregon/Washington	96	7	103
Gray whale	Eastern North Pacific	43	1	44
MF Cetaceans				
Sperm whale	California/Oregon/Washington	72	0	72
Baird's beaked whale	California/Oregon/Washington	84	0	84
Small beaked whale	California/Oregon/Washington	242	0	242
Bottlenose dolphin	California/Oregon/Washington (offshore)	13	0	13
Striped dolphin	California/Oregon/Washington	46	0	46
Short-beaked common dolphin	California/Oregon/Washington	179	0	179
Pacific white-sided dolphin	California/Oregon/Washington	6084	0	6084

Northern right-whale dolphin	California/Oregon/Washington	4318	0	4318
Risso's dolphin	California/Oregon/Washington	1664	0	1664
False killer whale	Hawai'i Pelagic	5	0	5
Killer whale	Southern Resident	10	0	10
	Northern Resident	73	0	73
	West Coast Transient			
	Offshore			
Short-finned pilot whale	California/Oregon/Washington	29	0	29
HF Cetaceans				
Pygmy/dwarf sperm whale	California/Oregon/Washington	125	5	130
Dall's porpoise	California/Oregon/Washington	9762	488	10250
Harbor porpoise	Northern Oregon/Washington Coast	7958	283	8241
	Northern California/Southern Oregon			
Otariid Seals				
Northern fur seal	Eastern Pacific	4592	0	4592
	California			
Guadalupe fur seal	Mexico to California	2048	0	2048
California sea lion	U.S.	889	0	889
Steller sea lion	Eastern U.S.	7504	0	7504
Phocid Seals				
Northern elephant seal	California Breeding	2754	0	2754
Harbor seal	Oregon/Washington Coast	3887	0	3887

Table 2. Level B Harassment Zones by Water Depth

Water depth (m)	Level B harassment zone (m)
> 1000	6,733
100 – 1000	9,468
< 100	12,650

Table 3. Level A Harassment Zones by Hearing Group

Source (volume)	Threshold	Level A harassment zone (m)				
		LF cetaceans	MF cetaceans	HF cetaceans	Phocids	Otariids
36-airgun array (6,600 in^3)	SEL_{cum}	426.9	0	1.3	13.9	0
	Peak	38.9	13.6	268.3	43.7	10.6