United States Department of Commerce
National Marine Fisheries Service
United States Department of the Interior
Fish and Wildlife Service

National Marine Fisheries Service
West Coast Region.
1201 NE Lloyd BLVD, Suite 1100
Portland Or, 97232

U.S. Fish and Wildlife Service
Pacific Region
911 N.E. 11th Avenue
Portland, Oregon 97232-4181

Refer to NMFS No.: WCR-2016-5583
USFWS Ref. No.: 01EWFW00-2016-F-1325

October 2, 2017

Michelle Walker, Chief Regulatory Branch
U.S. Army Corps of Engineers
Seattle District
P.O. Box 3755
Seattle, Washington 98124-3755

Re: Joint Endangered Species Act Section 7(a)(2) Biological Opinion, Letter of Concurrence, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Pier 62 Reconstruction Project, Elliott Bay, City of Seattle, King County, Washington Fifth Field HUC 1711001904, Puget Sound/East Passage. (COE No. NWS-2016-296-WRD).

Dear Ms. Walker:

Thank you for your letters of September 15, 2016, requesting initiation of consultation with NOAA's National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS, jointly the Services) pursuant to section 7 of the Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531 et seq.). The joint biological opinion addresses both the U.S. Army Corps of Engineers proposal to issue a permit to the City of Seattle and NMFS' issuance of an Incidental Harrassment Authorization under Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA) associated with the Pier 62 Reconstruction Project. Thank you, also, for your request for consultation pursuant to the essential fish habitat (EFH) provisions in Section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1855(b)) for this action.

We concluded that the proposed actions, as proposed, are not likely to jeopardize the continued existence of of the following species and will not result in the destruction or adverse modification of the following designated critical habitat:

NMFS species:

- Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*)
- Puget Sound Chinook salmon critical habitat
- Southern Resident killer whale (*Orcinus orca*)
- Southern Resident killer whale critical habitat
- Humpback whale (*Megaptera novaeangliae*)
- Georgia Basin bocaccio (*Sebastes paucispinis*)
- Georgia Basin bocaccio critical habitat

USFWS species:
Coastal Recovery Unit bull trout (*Salvelinus confluentus*)

The Services have also concluded that the proposed actions may affect, but are not likely to adversely affect the following species and designated critical habitat:

NMFS species:
Puget Sound steelhead (*O. mykiss*)
Georgia Bason yelloweye rockfish (*S. ruberrimus*)
Georgia Bason yelloweye rockfish critical habitat

FWS species:
Marbled murrelet (*Brachyramphus marmoratus*)
Coastal Recovery Unit bull trout critical habitat

Please contact Jim Muck, at the Services' office in Lacey, WA, email: jim_muck@fws.gov, phone: (360) 753-9586, if you have any questions concerning this consultation, or if you require additional information.

Sincerely,

for

Barry A. Thom
Regional Administrator
West Coast Region
National Marine Fisheries Service

for

Eric V. Rickerson
State Supervisor
Washington Fish and Wildlife Service
U.S. Fish and Wildlife Service

cc: J. Printz, COE

Joint National Marine Fisheries Service's and U.S. Fish and Wildlife Service's Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion, Letter of Concurrence, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation

for the

Pier 62 Reconstruction Project, Elliott Bay, City of Seattle, King County, Washington
Fifth Field HUC 1711001904, Puget Sound/East Passage (COE No. NWS-2016-296-WRD)

NMFS Consultation Number: WCR-2016-5583

USFWS Ref. Number: 01EWFW00-2016-F-1325

Action Agency: U.S. Army Corps of Engineers

Affected Species and Service's Determinations:

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species or Critical Habitat?	Is Action Likely To Jeopardize the Species?	Is Action Likely To Destroy or Adversely Modify Critical Habitat?
NMFS Species				
Puget Sound Chinook Salmon (*Oncorhynchus tshawytscha*)	Threatened	Yes	No	No
Puget Sound Steelhead (*O. mykiss*)	Threatened	No	No	N/A
Georgia Basin Bocaccio (*Sebastes paucispinis*)	Endangered	Yes	No	No
Georgia Basin Yelloweye Rockfish (*S. ruberrimus*)	Threatened	No	No	No
Humpback Whale (*Megaptera novaeangliae*)	Endangered	Yes	No	N/A
Southern Resident Killer Whale (*Orcinus orca*)	Endangered	Yes	No	No
USFWS Species				
Coastal Recovery Unit Bull Trout (*Salvelinus confluentus*)	Threatened	Yes	No	No
Marbled Murrelet (*Brachyramphus marmoratus*)	Threatened	No	No	N/A

Fishery Management Plan That Describes EFH in the Project Area	Does Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast Salmon	Yes	No
Pacific Coast Groundfish	Yes	No
Coastal Pelagic Species	Yes	No

Consultation Conducted By: National Marine Fisheries Service
West Coast Region

U.S. Fish and Wildlife Service
Washington Fish and Wildlife Office

Issued By:

Barry A. Thom
Regional Administrator
West Coast Region
National Marine Fisheries Service

Eric V. Rickerson
State Supervisor
Washington Fish and Wildlife Service
U.S. Fish and Wildlife Service

Date: October 2, 2017

TABLE OF CONTENTS

1. INTRODUCTION

This Introduction section provides information relevant to the other sections of this document and is incorporated by reference into Sections 2 and 3 below.

1.1 Background

The National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS, jointly, the Services) prepared the biological opinion (opinion) and incidental take statement (ITS) portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 USC 1531 et seq.), and implementing regulations at 50 CFR 402. 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 600.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (DQA) (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). A complete record of this consultation is on file at the Oregon and Washington Coastal Office in Portland, Oregon, and the Washington Fish and Wildlife Office in Lacey, Washington.

1.2 Consultation History

The U.S. Army Corps of Engineers (COE) proposes to issue a permit, and NMFS proposes to issue an Incidental Harassment Authorization (IHA) under Section 101 (a)(5)(D) of the Marine Mammal Protection Act (MMPA), to the City of Seattle (City or Seattle) for the proposed Pier 62 Reconstruction Project.

The Services reviewed and provided comments on a draft of the Joint Aquatic Resources Permit Application Form and Specific Project Information Forms for the project. Comments were provided on August 1, 19, and 31, 2016. The COE requested consultation on September 15, 2016. On October 19, 2016, the COE forwarded to the Services a revised Memorandum for the Services and Joint Aquatic Resources Permit Application.

On November 30, 2016, the Services attended a meeting with the City of Seattle, COE, Washington Department of Fish and Wildlife, Muckleshoot Indian Tribe, and the Suquamish Tribe on ways to reduce the impact of the project. At the meeting, it was confirmed that the COE will reduce the impact of the increase in overwater structure, by removing an equivalent amount of overwater structure from the west end of Pier 63.

On December 1, 2016, we received an email from Jill Macik, Seattle Department of Transportation, to Darren Habel, COE, on impact-reducing changes to the project that were discussed at the November 30, 2016, meeting.

On February 9, 2017, we received an email from Jill Macik to Darren Habel requesting to change the in-water work window from October 1 – February 15 to September 1 – March 1.

On February 21, 2017, we received an email from Jill Macik providing additional detail on the schedule and sequence of in-water work. Changes to project included working in-water the first construction season from August through February and September through February the second year. This scheduled was verified in an email on March 2, 2017, which also verified the following impact pile strike information: four piles per day will be installed with 20 strikes per pile.

On March 9 and 13, we received emails from Jill Macik clarifying when impact pile driving will be occurring during the two construction seasons.

On March 31, 2017, the Services emailed the City the draft Reasonable and Prudent Measures and Terms and Conditions for the project.

On May 24, 2017, NMFS' Office of Protected Resources' Permits and Conservation Division forwarded the Services a revised Request for Incidental Harassment Authorization (dated May 23, 2017) under the Marine Mammal Protection Act for the Pier 62 Project.

On May 25, 2017, the Services emailed to Stephanie Egger (NMFS' Permits and Conservation Division) and Mark Mazzola (Seattle Department of Transportation) a table with differences between the IHA Application and the information in the opinion obtained from the COE's consultation package and emails with project updates and revisions.

On June 1, 2017, the Services received a revised Request for Incidental Harassment Authorization (dated May 30, 2017) application.

On June 1, 2017, the Services received an email from Jill Macik on soft starts for impact pile driving.

On June 5, 2017, the Services received an email from Jill Macik with a Memo from Jill Macik to Daniel Krenze (COE) with initial response to differences between the IHA Application and the opinion. Revisions of the Memo were also received on June 6 and 15, 2017.

On June 12, 2017, the Services received the request for consultation from NMFS' Office of Protected Resources' Permits and Conservation Division for issuance of the IHA.

On June 12, 2017, the Services initiated consultation.

On June 22, 2017, the Services received a final version of the Memo from Jill Macik to Daniel Krenze.

In the COE's request for consultation, the COE determined that the proposed action "may affect, not likely to adversely affect" Southern Resident (SR) killer whales and humpback whales.

However, because NMFS is requesting consultation on the issuance of the IHA on these species, the Services do not concur with the COE's effect determinations.

The COE also determined that the proposed action "may affect, not likely to adversely affect" Georgia Basin (GB) bocaccio (*Sebastes paucispinus*), and designated critical habitat for Chinook salmon (*Oncorhynchus tshawytscha*), SR killer whale, and GB bocaccio. After review of the project, its construction schedule, and analyzing the effects of the action, we determined that the project will have adverse effect to these species and designated critical habitat. Therefore, the effects to these species and designated critical habitat are addressed in this opinion.

The COE made a determination that the proposed action "may affect, not likely to adversely affect" GB canary rockfish (*S. pinniger*). On January 23, 2017, NMFS issued a final rule to remove GB canary rockfish from the Federal List of Threatened and Endangered Species. The final rule became effective on March 24, 2017. The Services initiated consultation on June 12, 2017. Therefore, the Services did not include GB canary rockfish in this analysis.

1.3 Proposed Federal Action

"Action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies (50 CFR 402.02). "Interrelated actions" are those that are part of a larger action and depend on the larger action for their justification. "Interdependent actions" are those that have no independent utility apart from the action under consideration (50 CFR 402.02). No interrelated or interdependent actions are associated with the Pier 62 Reconstruction Project. Pier 62 is currently used for strolling, viewing, and recreation and cultural events. It was used for concerts, but because of its current condition, it has not been used for that venue for a while. Pier use will not change because of reconstruction and will continue to be used by the public. The new floating dock, added to the sourthern edge of Pier 62, will provide short-term daily moorage for small boats, a launch point for kayaks or for cultural events, and means for the public to get upclose to the water. The new floating dock will not result in additional effects, i.e. increased boat traffic, increased underwater sound, etc., that does not currently exist within Elliott Bay.

This opinion addresses two separate, but related activities: (1) The COE's issuance of a permit to the City for the Pier 62 Reconstruction Project, and (2) NMFS' issuance of an Incidental Harassment Authorization (IHA) under Section 101 (a)(5)(D) of the MMPA for this activity. Each action is introduced below. For the rest of the document, the action or proposed action refers to both activities.

1.3.1 Pier 62 Reconstruction Project.

Seattle Parks and Recreation proposes to demolish and then rebuild Pier 62 due to the existing structure needing significant repairs and replace a portion of Pier 63 in the nearshore with grating. Specific project features proposed by the City include:

- Demolition of 38,900 square feet of existing pier.

- Removal of 880 creosote-treated timber piles. Piles will be removed by either vibratory or direct pull methods. If piles cannot be fully extracted they will be cut two feet below the mud line.
- Installation of 180 steel piles, 30-inch diameter, with a vibratory pile driver. Impact pile driving will be used if obstructions or difficult ground conditions are encountered.
- Installation of concrete pile caps
- Installation of a 32,300 square foot concrete apron
- Installation of 5,900 square feet of grated decking along the shoreline
- Installation of 3,200 square feet of floats to allow a moorage system for transient, small-boat traffic.
- Removal of approximately 3,700 square feet along the western edge of Pier 63.
- Installation of nine steel piles, 30-inching diameter, to provide structural support to the new pier end.

Minimization Measures and Best Management Practices

A variety of minimization measures and best management practices (BMPs) will be implemented prior to or during construction to avoid, reduce, or minimize the potential for direct and indirect effects of the project. Minimization measures are found in the Specific Project Information Forms. These measures are designed to reduce or eliminate disturbances from increase sound pressure levels, turbidity and suspended sediments, and resuspension of contaminants.

Specific measures and practices that will be employed that will avoid, reduce, or minimize impact to listed species include:

- In-water construction will occur from August 1 to February 28 the first construction season and September 1 to February 28 the second season. The approved work window for Elliott Bay is July 16 to February 15. The City of Seattle has requested an extension of the work window to February 28.
- A bubble curtain will be used during impact pile driving activities.
- A sediment curtain will be installed around all in-water activities.
- All treated wood removed will be contained on land or barge to preclude sediments and contaminated material from entering the water and will be disposed of at an approved off-site location.
- Hydroacoustic monitoring will occur on a subset of pile driving activities to verify an 8 dB sound attenuation level.
- Monitoring for marine mammals during pile driving activities.
- Development and implementation of an onsite spill and prevention plan during construction.

1.3.2 NMFS Proposed Issuance of a Letter of Authorization

The NMFS's Permits and Conservation Division (PR1) is proposing to issue an IHA under Section 101(a)(5)(D) of the MMPA for the above identified City project. In order to issue the IHA, NMFS proposed to set forth the permissible methods of taking pursuant to the activity, and other means of affecting the least adverse impact practicable on such species or stock, and its

habitat. NMFS must also set forth requirements pertaining to the monitoring and reporting of such taking that will result in increased knowledge of the species and of the level of taking or impacts on populations of marine mammals that are expected to be present.

On June 1, 2017, PR1 received an adequate and complete application from the City to take marine mammals incidental to pile driving activities. PRl received an initial draft of the request on January 27, 2017, followed by a revised draft on May 23, 2017. The application included the measures presented below:

1) A bubble curtain will be used during pile driving with an impact hammer;

2) Exclusion zones will be established outside of the permanent threshold shift (PTS) isopleths to protect marine mammals from Level A harassment (Table 1);
   a) If a killer whale or humpback whale is observed at or within the Exclusion Zone, work will stop until the individual has been observed outside of the zone, or has not been observed for at least 30 minutes. In addition, acoustic monitoring will occur on up to six days per in-water work season to evaluate, in real time, sound production from construction activities.

3) A " soft-start" will be used for impact pile driving - initial set of three strikes from the impact hammer at reduced energy, followed by a one-minute waiting period, then two subsequent three-strike sets;

4) Marine mammal monitoring by NMFS-approved protected species observers (PSOs) will be deployed during pile driving activities;
   a) During pile removal or installation with a vibratory hammer, a three-monitor protocol will be used.
   b) During impact pile driving, one monitor will conduct the monitoring.
   c) If visibility becomes limited, additional land-based or boat-based monitors may be deployed.
   d) Implementation of shut-down procedures when marine mammals are detected within or about to enter the exclusion zone to reduce the noise exposure level to below that which could cause injury to the marine mammals.

5) Acoustic monitoring will be conducted during in-water pile removal and installation for a minimum of two days for each type of pile-related activity (vibratory and impact pile driving).
   a) Collection of acoustic data will be accomplished using a minimum of two hydrophones. At least one land-based microphone will be used to record airborne sound levels.
   b) All in-water acoustical recording will be conducted approximately one meter below the water surface and one meter above the seafloor, or as applicable to optimize sound recordings in the nearshore environment.

Table 1. Established exclusion zone thresholds (distance to 160 dB_{RMS} [Level A harrassment]) and distance to disturbance thresholds (distance to 124 dB_{RMS} [Level B harassment]) for pile driving activities.

Action Type	Level A Harassment Distance to 160 dB_{RMS} Impact Disturbance Threshold from Measured Sound (meters)	Level B Harassment Distance to 124 dBRMS Vibratory Disturbance Threshold (Background) from Measured Sound (meters)	Source Sound
Impact Driving – 30-inch Steel Pipe Piles	1,201	N/A	189 dB_{RMS}
Vibratory Driving – 30-inch Steel Pipe Piles	N/A	54,117	180 dB_{RMS}
Vibratory Removal – 14-inch Timber Piles	N/A	1,865	155 dB_{RMS}

Note: dB_{RMS} – decibels, root mean square pressure level.

2. ENDANGERED SPECIES ACT: BIOLOGICAL OPINION AND INCIDENTAL TAKE STATEMENT

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, each Federal agency must insure that its actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. Per the requirements of the ESA, Federal action agencies consult with the Services and section 7(b)(3) requires that, at the conclusion of consultation, the Services provide an opinion stating how the agency's actions will affect listed species and their critical habitats. If incidental take is reasonably certain to occur, section 7(b)(4) requires the Service to provide an ITS that specifies the impact of any incidental taking and includes non-discretionary reasonable and prudent measures (RPMs) and terms and conditions to minimize such impacts.

The COE determined the proposed action is not likely to adversely affect PS steelhead (*Oncorhynchus mykiss*), , marbled murrelet (*Brachyramphus marmoratus*), yelloweye (*S. ruberrimus*) rockfish, and designated bull trout (*Salvelinus confluentus*) and yelloweye critical habitat. Our concurrence is documented in the "Not Likely to Adversely Affect" Determinations Section (2.12).

2.1 Analytical Approach

This opinion includes a jeopardy analysis and an adverse modification 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 CFR 402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species.

This biological opinion relies on the definition of "destruction or adverse modification," which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features" (81 FR 7214).

The designation of critical habitat for Chinook salmon, bocaccio, and killer whales uses the term primary constituent element (PCE) or essential features. The new critical habitat regulations (81 FR 7414) replace this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a ''destruction or adverse modification'' analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

We use the following approach to determine whether a proposed action is likely to jeopardize listed species or destroy or adversely modify critical habitat:

- Identify the rangewide status of the species and critical habitat expected to be adversely affected by the proposed action.
- Describe the environmental baseline in the action area.
- Analyze the effects of the proposed action on both species and their habitat using an "exposure-response-risk" approach.
- Describe any cumulative effects in the action area.
- Integrate and synthesize the above factors by: (1) Reviewing the status of the species and critical habitat; and (2) adding the effects of the action, the environmental baseline, and cumulative effects to assess the risk that the proposed action poses to species and critical habitat.
- Reach a conclusion about whether species are jeopardized or critical habitat is adversely modified.
- If necessary, suggest a RPA to the proposed action.

2.2 Rangewide Status of the Species and Critical Habitat

This opinion examines the status of each species that will be adversely affected by the proposed action. The status is determined by the level of extinction risk that the listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This informs the description of the species' likelihood of both survival and recovery. The species status section also helps to inform the description of the species' current "reproduction, numbers, or distribution" as described in 50 CFR 402.02. The opinion also examines the condition of critical habitat throughout the designated area, evaluates the conservation value of the various watersheds and coastal and marine environments that make up the designated area, and discusses the current function of the essential PBFs that help to form that conservation value.

2.2.1 Chinook Salmon

This Evolutionarily Significant Unit (ESU) was listed as a threatened species in1999; its threatened status was reaffirmed in 2005. The NMFS issued results of a five-year review on August 15, 2011 (NMFS 2016a), and concluded that this species should remain listed as threatened.

The NMFS adopted the recovery plan for Puget Sound (PS) Chinook on January 19, 2007 (72 FR 2493). The recovery plan consists of two documents: the Puget Sound Salmon Recovery Plan prepared by the Shared Strategy for Puget Sound and NMFS' Final Supplement to the Shared Strategy Plan. 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 the following conditions are achieved:

1. All watersheds improve from current conditions, resulting in improved status for the species;

2. At least two to four Chinook salmon populations in each of the five biogeographical regions of Puget Sound attain a low risk status over the long-term;

3. At least one or more populations from major diversity groups historically present in each of the five Puget Sound regions attain a low risk status;

4. 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;

5. 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.

Spatial Structure and Diversity. The PSTRT determined that 22 historical populations currently contain Chinook salmon and grouped them 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. Ruckelshaus et al. (2002) recommended for the recovery of Chinook salmon at least two viable populations per geographic region. Based on genetic and historical evidence reported in the literature, the PSTRT also determined that there were 16 additional spawning aggregations or populations in the Chinook Salmon ESU that are now putatively extinct[1] (Ruckelshaus et al. 2006). This ESU includes all naturally spawned populations of Chinook salmon from rivers and streams flowing into Puget Sound including the Straits of Juan De Fuca from the Elwha River, eastward, including rivers and streams flowing into Hood Canal, South Sound, North Sound and the Strait of Georgia in Washington, and progeny of 26 artificial propagation programs.

[1] It was not possible in most cases to determine whether these Chinook salmon spawning groups historically represented independent populations or were distinct spawning aggregations within larger populations.

Between 1990 and 2014, the proportion of natural-origin spawners has trended downward across the ESU, with the Whidbey Basin the only major population group (MPG) with consistently high fractions of natural-origin spawner abundance. All other MPGs have either variable or declining spawning populations with high proportions of hatchery-origin spawners (NWFSC 2015). Overall, the new information on abundance, productivity, spatial structure and diversity since the 2010 status review supports no change in the biological risk category (NWFSC 2015).

Abundance and Productivity. Escapement levels for all populations remain well below the PSTRT planning ranges for recovery, and most populations are consistently below the spawner-recruit levels identified by the PSTRT as consistent with recovery (NWFSC 2015).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 (NWFSC 2015). However, most populations exhibit a stable or increasing growth rate in natural-origin escapement (after harvest). No clear patterns in trends in escapement or abundance are evident among the five major regions of Puget Sound. No trend was notable for total ESU escapements. Trends in growth rate of natural-origin escapement are generally higher than growth rate of natural-origin abundance indicating some stabilizing influence on escapement from past reductions in fishing-related mortality. Survival and recovery of the Chinook salmon ESU will depend, over the long term, on necessary actions in all "4 H" sectors (hatcheries, habitat, harvest and hydro). Many of the habitat and hatchery actions identified in the Chinook salmon recovery plan are likely to take years or decades to be implemented and to produce significant improvements in natural population attributes, and these trends are consistent with these expectations and reiterated in Ford (2011).

Limiting factors. Limiting factors described in SSPS (2007) and NMFS (2011) include:

- Degraded nearshore and estuarine habitat: Residential and commercial development has reduced the amount of functioning nearshore and estuarine habitat available for salmon rearing and migration. The loss of mudflats, eelgrass meadows, and macroalgae further limits salmon foraging and rearing opportunities in nearshore and estuarine areas.

- Degraded freshwater habitat: Floodplain connectivity and function, channel structure and complexity, riparian areas and large wood supply, stream substrate, and water quality have been degraded for adult spawning, embryo incubation, and rearing as a result of cumulative impacts of agriculture, forestry, and development.

- Anadromous salmonid hatchery programs: Salmon and steelhead released from Puget Sound hatcheries operated for harvest augmentation purposes pose ecological, genetic, and demographic risks to natural-origin Chinook salmon populations. Salmon harvest management: Total fishery exploitation rates have decreased 14 to 63 percent from rates in the 1980s, but weak natural-origin Chinook salmon populations in Puget Sound still require enhanced protective measures to reduce the risk of overharvest.

2.2.2 Bocaccio

The Puget Sound/Georgia Basin Distinct Population Segments (DPS) of bocaccio was listed under the ESA as endangered on April 28, 2010 (75 FR 22276). The DPS includes all bocaccio found in waters of the Puget Sound, the Strait of Georgia, and the Strait of Juan de Fuca east of Victoria Sill. Unlike ESA-listed salmonids, NMFS has not identified biological populations of bocaccio below the DPS level, and thus use the term "populations" to refer to groups of fish within a particular basin of the DPS. Bocaccio is one of 28 species of rockfish in Puget Sound (Palsson et al. 2009).

The life-history of bocaccio includes a larval/pelagic juvenile stage followed by a nearshore juvenile stage, and sub-adult and adult stages. Rockfish fertilize their eggs internally, and the young are extruded as larvae. Bocaccio produce from several thousand to over a million eggs (Love et a1. 2002). Larvae can make small local movements to pursue food immediately after birth (Tagal et al. 2002), but are likely passively distributed with prevailing currents (NMFS 2003). Larvae are observed under free-floating algae, seagrass, and detached kelp (Love et al. 2002; Shaffer et al. 1995) but are also distributed throughout the water column (Weis 2004). Unique oceanographic conditions within Puget Sound proper likely result in most larvae staying within the basin where they are released (e.g., the South Sound) rather than being broadly dispersed (Drake et al. 2010).

When bocaccio reach sizes of 1 to 3.5 in (3 to 9 cm) (approximately 3 to 6 months old), they settle onto shallow nearshore waters in rocky or cobble substrates with or without kelp (Love et a1. 1991, 2002). These habitat features offer a beneficial mix of warmer temperatures, food, and refuge from predators (Love et al. 1991). Areas with floating and submerged kelp species support the highest densities of most juvenile rockfish (Carr 1983; Halderson and Richards 1987; Hayden-Spear 2006; Matthews 1989).

Sub-adult and adult bocaccio typically utilize habitats with moderate to extreme steepness, complex bathymetry, and rock and boulder-cobble complexes (Love et al. 2002). Within Puget Sound proper, bocaccio have been documented in areas of high relief rocky and non-rocky substrates such as sand, mud, and other unconsolidated sediments (Miller and Borton 1980; Washington 1977). Bocaccio tend to have large home ranges, move long distances, and spend time suspended in the water column (Love et al. 2002). Adults are most commonly found between 131 feet to 820 feet (40 to 250 m) (Love et a1. 2002; Orr et al. 2000).

Rockfish are known to live a long time. The maximum age of bocaccio is unknown, but may exceed 50 years, and they are first reproductively mature near age six (FishBase 2010). The timing of larval release varies throughout the geographic range. In Puget Sound, there is some evidence that larvae are extruded in early spring to late summer (Washington et al. 1978). Along the coast of Washington State, female bocaccio release larvae between January and April (Love et al. 2002).

Spatial Structure and Connectivity. Spatial structure consists of a population's geographical distribution and the processes that generate that distribution (McElhaney et al. 2000). A population's spatial structure depends on habitat quality, spatial configuration, and dynamics as

well as dispersal characteristics of individuals within the population (McElhaney et al. 2000). Rockfish are able to utilize the full suite of available habitats to maximize their abundance and demographic characteristics, thereby enhancing their resilience (Hamilton 2008). This distribution also enables rockfish to potentially exploit ephemerally good habitat conditions, or in turn receive protection from smaller-scale and negative environmental fluctuations. These types of fluctuations may change prey abundance for various life stages and/or may change environmental characteristics that influence the number of annual recruits.

Spatial distribution provides a measure of protection from larger scale anthropogenic changes that damage habitat suitability, such as oil spills or hypoxia that can occur within one basin, but not necessarily the other basins (NMFS 2016b). Rockfish population resilience is sensitive to changes in connectivity among various groups of fish (Hamilton 2008). Hydrologic connectivity of the basins of the Puget Sound is naturally restricted by relatively shallow sills located at Deception Pass, Admiralty Inlet, the Tacoma Narrows, and in Hood Canal (Burns 1985). These sills regulate water exchange from one basin to the next, and thus likely moderate the movement of rockfish larvae (Drake et al. 2010). When localized depletion of rockfish occurs, it can reduce stock resiliency (Hamilton 2008; Hilborn et al. 2003). The effects of localized depletions of rockfish are likely exacerbated by the natural hydrologic constrictions within Puget Sound.

Bocaccio Spatial Structure and Connectivity. Most bocaccio within the DPS may have been historically spatially limited to several basins. They were historically most abundant in the Central and South Sound (Drake et al. 2010) with no documented occurrences in the San Juan Basin until 2008 (WDFW 2011a). Positive signs for spatial structure and connectivity come from the propensity of some adults and pelagic juveniles to migrate long distances, which could re-establish aggregations of fish in formerly occupied habitat (Drake et al. 2010). The apparent reduction of populations of bocaccio in the Main Basin and South Sound represents a further reduction in the historically spatially limited distribution of bocaccio, and adds significant risk to the viability of the DPS (NMFS 2016b).

Diversity. Characteristics of diversity for rockfish include fecundity, timing of the release of larvae and their condition, morphology, age at reproductive maturity, physiology, and molecular genetic characteristics. In spatially and temporally varying environments, there are three general reasons why diversity is important for species and population viability: 1) diversity allows a species to use a wider array of environments; 2) it protects a species against short-term spatial and temporal changes in the environment; and 3) genetic diversity provides the raw material for surviving long-term environmental changes. Though there are no genetic data for the ESA-listed rockfish DPSs, the unique oceanographic features and relative isolation of some of its basins may have led to unique adaptations, such as timing of larval release (Drake et al. 2010).

Bocaccio Diversity. Size-frequency distributions for bocaccio in the 1970s indicate a wide range of sizes, with recreationally caught individuals from 9.8 to 33.5 in (25 to 85 cm). This broad size distribution suggests a spread of ages, with some successful recruitment over many years. A similar range of sizes is also evident in the 1980s catch data. The temporal trend in size distributions for bocaccio also suggests size truncation of the population, with larger fish becoming less common over time. By the decade of the 2000s, no size distribution data for bocaccio were available. Bocaccio in the Puget Sound/Georgia Basin may have physiological or

behavioral adaptations because of the unique habitat conditions in the range of the DPS. The potential loss of diversity in the bocaccio DPS, in combination with their relatively low productivity, may result in a mismatch with habitat conditions and further reduce population viability (Drake et al. 2010).

Abundance and Productivity. There is no single reliable historical or contemporary population estimate for bocaccio within the Puget Sound/Georgia Basin DPS (Drake et a1. 2010). Despite this limitation, there is clear evidence their abundance has declined dramatically (Drake et a1. 2010). The total rockfish population in the Puget Sound region is estimated to have declined around three percent per year for the past several decades, which corresponds to an approximate 70 percent decline from the 1965 to 2007 time period (Drake et a1. 2010). Catches of bocaccio have declined as a proportion of the overall rockfish catch (Drake et a1. 2010; Palsson et a1. 2009).

Present-day abundance of bocaccio is influenced by bycatch from several commercial and recreational fisheries. Though rockfish may no longer be retained in these fisheries, released fish are often injured or killed by barotrauma. When rockfish are brought from depths of deeper than 60 feet (18.3 meters) the rapid decompression causes over-inflation and/or rupture of the swim bladder (termed barotrauma), which can result in multiple injuries (Jarvis and Lowe 2008; Palsson et a1. 2009; Parker et a1. 2006). These injuries cause various levels of disorientation among rockfish species, which result in fish remaining at the surface after they are released (Hannah and Matteson 2007). Rockfish at the surface are susceptible to predation by birds, sharks, or marine mammals, damage from solar radiation, and gas embolisms (Palsson et a1. 2009).

Fishery-independent estimates of population abundance come from spatially and temporally limited research trawls, drop camera surveys, and underwater remotely operated vehicle (ROV) surveys conducted by WDFW. The trawl surveys were conducted on the bottom to assess marine fish abundance for a variety of species. These trawls generally sample over non-rocky substrates where bocaccio are less likely to occur compared to steep-sloped, rocky habitat (Drake et al. 2010). The drop camera surveys sampled habitats less than 120 feet (36.6 meters), which is potential habitat for juveniles, but less likely habitat for adults.

The WDFW ROV surveys were conducted exclusively within the rocky habitats of the San Juan Basin in 2008, and represent the best available abundance estimates for one basin of the DPS because of their survey area, number of transects, and stratification methods. Rocky habitats have been mapped within the San Juan Basin, which allows a randomized survey of these areas to assess rockfish assemblages and collect data for abundance estimates. WDFW conducted 200 transects and stratified each rocky habitat survey as either "shallower than" and "deeper than" 120 feet (36.6 meters). The total area surveyed within each stratum was calculated using the average transect width multiplied by the transect length. The mean density of bocaccio was calculated by dividing the species counts within each stratum by the area surveyed. Population estimates were calculated by multiplying density estimates by the total survey area within each stratum (WDFW unpublished data). Because WDFW did not survey non-rocky habitats of the San Juan Basin with the ROV, these estimates do not account for ESA-listed rockfish in non-rocky habitat in 2008.

Though the bottom trawl and drop camera surveys did not detect bocaccio in Puget Sound proper, bocaccio have been historically present and has been caught in recent recreational fisheries. The lack of detected bocaccio from these sampling methods in Puget Sound proper is probably due to the following factors: 1) populations of bocaccio are depleted; 2) the general lack of rocky benthic areas in Puget Sound proper may lead to densities that are naturally less than the San Juan Basin; and 3) the study design or effort may not have been sufficiently powerful to detect bocaccio.

Productivity is the measurement of a population's growth rate through all or a portion of its lifecycle. Life-history traits of bocaccio suggest generally low levels of inherent productivity because they are long-lived, mature slowly, and have sporadic episodes of successful reproduction (Drake et al. 2010; Tolimieri and Levin 2005). Historical over-fishing can have dramatic impacts on the size or age structure of the population, with effects that can influence ongoing productivity. When the size and age of females decline, there are negative impacts to reproductive success. These impacts, termed maternal effects, are evident in a number of traits. Larger and older females of various rockfish species have a higher weight-specific fecundity (number of larvae per unit of female weight) (Bobko and Berkeley 2004; Boehlert et al. 1982; Sogard et al. 2008). A consistent maternal effect in rockfishes relates to the timing of parturition. The timing of larval birth can be crucial in terms of corresponding with favorable oceanographic conditions because most larvae are released on only 1 day each year, with a few exceptions in southern coastal populations (Washington et al. 1978). Several studies of rockfish species have shown that larger or older females release larvae earlier in the season compared to smaller or younger females (Nichol and Pikitch 1994; Sogard et al. 2008). Larger or older females provide more nutrients to larvae by developing a larger oil globule released at parturition, which provides energy to the developing larvae (Berkeley et al. 2004; Fisher et al. 2007), and in black rockfish enhances early growth rates (Berkeley et al. 2004).

Bocaccio Abundance and Productivity. Bocaccio in the Puget Sound/Georgia Basin were historically most common within the South Sound and Central Sound Basins (Drake et al. 2010). Bocaccio consisted of eight to nine percent of the overall rockfish catch in the late 1970s and declined in frequency, relative to other species of rockfish, from the 1970s to the 1990s (Drake et al. 2010). From 1975 to 1979, bocaccio averaged 4.63 percent of the catch. From 1980 to 1989, they were 0.24 percent of the 8,430 rockfish identified (Palsson et al. 2009). In the 1990s and early 2000s bocaccio were not observed by WDFW in the dockside surveys of the recreational catches (Drake et al. 2010). In 2008 and 2009, some fish were reported by recreational anglers in the Central Sound (WDFW 2011a).

Though bocaccio were never a predominant segment of the multi-species rockfish population within the Puget Sound/Georgia Basin (Drake et al. 2010), their present-day abundance is likely a fraction of their pre-contemporary fishery abundance. Bocaccio abundance may be very low in significant segments of the Puget Sound/Georgia Basin. From 1998 to 2008, fish were reported by anglers in only one basin of the DPS range. Productivity is driven by high fecundity and episodic recruitment events, largely correlated with environmental conditions. Thus, bocaccio populations do not follow consistent growth trajectories and sporadic recruitment drives population structure (Drake et al. 2010). Natural annual mortality is approximately eight percent (Palsson et. al 2009). Tolimieri and Levin (2005) found that the bocaccio population growth rate

is around 1.01, indicating a very low intrinsic growth rate for this species. Demographically, this species demonstrates some of the highest recruitment variability among rockfish species, with many years of failed recruitment being the norm (Tolimieri and Levin 2005). Given their severely reduced abundance, Allee effects may be particularly acute for bocaccio, even considering the propensity of some individuals to move long distances and potentially find mates.

Limiting Factors. Contaminants such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers, and chlorinated pesticides appear in rockfish collected in urban areas (Palsson et al. 2009). While the highest levels of contamination occur in urban areas, toxins can be found in the tissues of fish throughout Puget Sound (West et al. 2001). Although few studies have investigated the effects of toxins on rockfish ecology or physiology, other fish in the Puget Sound region that have been studied do show a substantial impact, including reproductive dysfunction of some sole species (Landahl et a1. 1997). Reproductive function of rockfish is also likely affected by contaminants (Palsson et al. 2009) and other life-history stages may be as well (Drake et a1. 2010).

Climate-induced changes to rockfish habitat could alter their productivity (Drake et a1. 2010). Harvey (2005) created a generic bioenergetic model for rockfish, showing that productivity of rockfish is highly influenced by climate conditions. For instance, EI Nino-like conditions generally lowered growth rates and increased generation time. The negative effect of the warm water conditions associated with El Nino appear to be common across rockfishes (Moser et a1. 2000). Recruitment of all species of rockfish appears to be correlated at large scales. Field and Ralston (2005) hypothesized that such synchrony was the result of large-scale climate forcing. Exactly how climate influences rockfish in Puget Sound is unknown; however, given the general importance of climate to rockfish recruitment, it is likely that climate strongly influences the dynamics of ESA-listed rockfish population viability (Drake et a1. 2010).

Bocaccio exist at very low abundance, and observations are rare within this DPS. Their low intrinsic productivity, combined with continuing threats from bycatch in commercial and recreational harvest, non-native species introductions, loss and degradation of habitat, and chemical contamination, increase the extinction risk. NMFS has determined that this DPS is currently in danger of extinction throughout all of its range (Drake et al. 2010).

2.2.3 Southern Resident Killer Whale

The Southern Resident (SR) killer whale Distinct Population Segment (DPS) was listed as endangered under the ESA on November 18, 2005 (70 FR 69903). Southern Residents are designated as depleted and strategic under the Marine Mammal Protection Act (May 29, 2003, 68 FR 31980). NMFS issued the final recovery plan for SR killer whales in January 2008 (NMFS 2008).

Southern Resident killer whales are a long-lived species, with late onset of sexual maturity (NMFS 2008). Mothers and offspring maintain highly stable social bonds throughout their lives, which is the basis for the matrilineal social structure in the SR killer whale population (NMFS 2008). Groups of related matrilines form pods. Three pods – J, K, and L – make up the SR killer

whale DPS. All SR killer whales are individually identified by photo-identification based on uniquely shaped and scarred dorsal fins and saddle patches (The Center for Whale Research unpubl. data).

Vocal communication is advanced in killer whales and is important to their social structure, navigation and foraging (NMFS 2008). Southern Resident killer whales consume a variety of fish and one species of squid, but salmon, and Chinook salmon in particular, are their primary prey (Ford and Ellis 2006, Hanson et al. 2010).

Spatial Distribution and Diversity. The SR killer whale DPS is composed of a single population that ranges as far south as central California and as far north as Southeast Alaska. From late spring to early autumn, SR killer whales spend considerable time in the Salish Sea, with concentrated activity around the San Juan Islands and then move south into Puget Sound in early autumn. Pods make frequent trips to the outer coast during this time. Although the entire SR killer whale DPS has the potential to occur along the outer coast at any time during the year, occurrence along the outer coast is more likely from late autumn to early spring.

The estimated effective size of the population (based on the number of breeding individuals under ideal genetic conditions) is very small <30 whales or about 1/3 of the current population size (Ford et al. 2011). The small effective population size, 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 2011). In addition, the small effective population size may contribute to the lower growth rate of the SR killer whale population in contrast to the Northern Resident population (Ford 2011, Ward et al. 2009).

Abundance and Productivity. As of December 31, 2016, there were 24 whales in J pod, 19 whales in K pod and 35 whales in L pod, for a total of 78 whales (Center for Whale Research 2017). The historical abundance of SR killer whales is estimated from 140 whales (based on public display removals; Olesiuk et al. 1990) up to 400 whales as used in population viability assessment scenarios (Krahn et al. 2004). Between 1983 and 2010, population growth has been variable, with an average annual population growth rate of 0.3 percent and standard deviation of ± 3.2 percent (The Center for Whale Research unpubl. data).

A delisting criterion for the SR killer whale DPS is an average growth rate of 2.3 percent for 28 years (NMFS 2008). With the average growth rate of 0.3 percent, this recovery criterion has not yet been met (Wiles 2016) and the low population growth rate is not sufficient to achieve recovery. There are also several demographic factors of the SR killer whale population that are cause for concern, namely the small number of breeding males (particularly in J and K pods), reduced fecundity, decreased sub-adult survivorship in L pod, and the total number of individuals in the population (NMFS 2008).

Limiting Factors. Several factors identified in the final recovery plan for SR killer whales may be limiting recovery. These are quantity and quality of prey (particularly their primary prey, Chinook salmon), exposure to toxic chemicals that accumulate in top predators, and disturbance from sound and vessels. Oil spills are also a risk factor. It is likely that multiple threats are acting in concert to impact the whales. Although it is not clear which threat or threats are most

significant to the survival and recovery of SR killer whales, all of the threats identified are potential limiting factors in their population dynamics (NMFS 2008).

2.2.4 Humpback Whale

Humpback whales were listed as endangered under the Endangered Species Conservation Act (ESCA) in June 1970 (35 FR 18319) and they were listed as endangered under the ESA in 1973. NMFS issued the final recovery plan for humpback whales in November 1991 (NMFS 1991). In April 2015 NMFS published a proposed rule to identify 14 DPSs of humpback whales and list two as threatened and two as endangered (80 FR 22304). On September 8, 2016, NMFS published a final rule to divide the globally listed endangered humpback whale into 14 DPSs, remove the species-level listing, and place four DPSs as endangered and one as threatened (81 FR 62259). NMFS has identified three DPSs of humpback whales that may be found off the coasts of Washington, Oregon and California. These are the Hawaiian DPS (found predominately off Washington and southern British Columbia) which is not listed under the ESA; the Mexico DPS (found all along the coast) which is listed as threatened under the ESA; and the Central America DPS (found predominately off the coasts of Oregon and California) which is listed as endangered under the ESA.

Spatial Structure and Diversity. Humpback whales occur in all major oceans of the world. In the North Pacific, humpback whales feed in coastal waters from California to Russia, including in the Bering Sea. These humpback whales migrate south off Mexico, Central America, Hawaii, southern Japan, and the Philippines (Carretta et al. 2013). Significant levels of nuclear and mtDNA differences exist between the North Pacific humpback whale populations (Baker et al. 1998).

Humpback whales forage on a variety of crustaceans, other invertebrates, and forage fish (reviewed in NMFS 1991). In their summer foraging areas, humpback whales tend to occupy shallow, coastal waters. In contrast, during their winter migrations humpback whales tend to occupy deeper waters further offshore, and are less likely to occupy shallow, coastal waters.

Abundance and Productivity. Current estimates of abundance for the Central America DPS range from approximately 400 to 600 individuals (Bettridge et al. 2015; Wade et al. 2016). The size of this population is relatively low compared to most other North Pacific breeding populations. The population trend for the Central America DPS is unknown (Bettridge et al. 2015). The Mexico DPS, which also occurs in the action areas, is estimated to be 6,000 to 7,000 from the SPLASH project (Calambokidis et al. 2008) and in the status review (Bettridge et al. 2015). The population growth of California/Oregon feeding population of the North Pacific humpback whales has been estimated as increasing about 8 percent annually (the population growth rate for the entire North Pacific population is approximately 4.9 percent) (Calambokidis et al. 2008). The estimate for the abundance of the CA/OR/WA stock, which combines members of several different humpback whale DPS, is 1,918 animals (Carretta et al 2016).

Limiting Factors. Humpbacks globally are potentially affected by a resumption of commercial whaling, loss of habitat, loss of prey (for a variety of reasons including climate variability), underwater noise, and pollutants. Entanglement in fishing gear poses a threat to individual

humpback whales throughout the Pacific. The estimated impact of fisheries on the CA/OR/WA humpback whale stock is likely underestimated, since the serious injury or mortality of large whales due to entanglement in gear may go unobserved because whales swim away with a portion of the net, line, buoys, or pots. Humpback whales, especially calves and juveniles, are highly vulnerable to ship strikes (Stevick 1999) and other interactions with non-fishing vessels. Off the U.S. west coast, humpback whale distribution overlaps significantly with the transit routes of large commercial vessels, including cruise ships, large tug and barge transport vessels, and oil tankers in the proposed action area. Whale watching boats and research activities directed toward whales and may have direct or indirect impacts on humpback whales as harassment may occur, preferred habitats may be abandoned, and fitness and survivability may be compromised if disturbance levels are too high.

Along the U.S. west coast, the estimated annual mortality and serious injury of the CA/OR/WA stock of humpback whales due to commercial fishery entanglements (5.3/yr), and non-fishery entanglements (0.2/yr), other anthropogenic sources (zero), plus ship strikes (1.0/yr), equals 6.5 animals, which is less than the PBR allocation of 11 for U.S. waters (Carretta et al. 2016). Most data on human-caused serious injury and mortality for this population is based on opportunistic stranding and at-sea sighting data and represents a minimum count of total impacts. There is currently no estimate of the fraction of anthropogenic injuries and deaths to humpback whales that are undocumented on the U.S. west coast. Based on strandings and at sea observations, annual humpback whale mortality and serious injury in commercial fisheries (5.3/yr) is greater than 10% of the PBR; therefore, total fishery mortality and serious injury is not approaching zero mortality and serious injury rate (Carretta et al. 2016). The annual number of reported whale entanglements off the coasts of California, Oregon, and Washington was 71 in 2016. Of these, 54 were reports of humpback whale entanglement. Of the 48 confirmed whale entanglements that year, 42 were entangled humpback whales (NOAA Fisheries 2017).

2.2.5 Bull Trout

Taxonomy

The bull trout is a native char found in the coastal and intermountain west of North America. Dolly Varden (Salvelinus malma) and bull trout were previously considered a single species and were thought to have coastal and interior forms. However, Cavender (1978, entire) described morphometric, meristic and osteological characteristics of the two forms, and provided evidence of specific distinctions between the two. Despite an overlap in the geographic range of bull trout and Dolly Varden in the Puget Sound area and along the British Columbia coast, there is little evidence of introgression (Haas and McPhail 1991, p. 2191). The Columbia River Basin is considered the region of origin for the bull trout. From the Columbia, dispersal to other drainage systems was accomplished by marine migration and headwater stream capture. Behnke (2002, p. 297) postulated dispersion to drainages east of the continental divide may have occurred through the North and South Saskatchewan Rivers (Hudson Bay drainage) and the Yukon River system. Marine dispersal may have occurred from Puget Sound north to the Fraser, Skeena and Taku Rivers of British Columbia.

Species Description

Bull trout have unusually large heads and mouths for salmonids. Their body colors can vary tremendously depending on their environment, but are often brownish green with lighter (often ranging from pale yellow to crimson) colored spots running along their dorsa and flanks, with spots being absent on the dorsal fin, and light colored to white under bellies. They have white leading edges on their fins, as do other species of char. Bull trout have been measured as large as 103 centimeters (41 inches) in length, with weights as high as 14.5 kilograms (32 pounds) (Fishbase 2015, p. 1). Bull trout may be migratory, moving throughout large river systems, lakes, and even the ocean in coastal populations, or they may be resident, remaining in the same stream their entire lives (Rieman and McIntyre 1993, p. 2; Brenkman and Corbett 2005, p. 1077). Migratory bull trout are typically larger than resident bull trout (USFWS 1998, p. 31668).

Legal Status

The coterminous United States population of the bull trout (*Salvelinus confluentus*) was listed as threatened on November 1, 1999 (USFWS 1999a, entire). The threatened bull trout generally occurs in the Klamath River Basin of south-central Oregon; the Jarbidge River in Nevada; the Willamette River Basin in Oregon; Pacific Coast drainages of Washington, including Puget Sound; major rivers in Idaho, Oregon, Washington, and Montana, within the Columbia River Basin; and the St. Mary-Belly River, east of the Continental Divide in northwestern Montana (Bond 1992, p. 4; Brewin and Brewin 1997, pp. 209-216; Cavender 1978, pp. 165-166; Leary and Allendorf 1997, pp. 715-720).

Throughout its range, the bull trout are threatened by the combined effects of habitat degradation, fragmentation, and alterations associated with dewatering, road construction and maintenance, mining, grazing, the blockage of migratory corridors by dams or other diversion structures, poor water quality, entrainment (a process by which aquatic organisms are pulled through a diversion or other device) into diversion channels, and introduced non-native species (USFWS 1999a, p. 58910). Although all salmonids are likely to be affected by climate change, bull trout are especially vulnerable given that spawning and rearing are constrained by their location in upper watersheds and the requirement for cold water temperatures (Battin et al. 2007, entire; Rieman et al. 2007, entire; Porter and Nelitz. 2009, pages 4-8). Poaching and incidental mortality of bull trout during other targeted fisheries are additional threats.

Life History

The iteroparous reproductive strategy of bull trout has important repercussions for the management of this species. Bull trout require passage both upstream and downstream, not only for repeat spawning but also for foraging. Most fish ladders, however, were designed specifically for anadromous semelparous salmonids (fishes that spawn once and then die, and require only one-way passage upstream). Therefore, even dams or other barriers with fish passage facilities may be a factor in isolating bull trout populations if they do not provide a downstream passage route. Additionally, in some core areas, bull trout that migrate to marine waters must pass both upstream and downstream through areas with net fisheries at river mouths. This can increase the likelihood of mortality to bull trout during these spawning and foraging migrations.

Growth varies depending upon life-history strategy. Resident adults range from 6 to 12 inches total length, and migratory adults commonly reach 24 inches or more (Goetz 1989, p. 30; Pratt 1985, pp. 28-34). The largest verified bull trout is a 32-pound specimen caught in Lake Pend Oreille, Idaho, in 1949 (Simpson and Wallace 1982, p. 95).

Bull trout typically spawn from August through November during periods of increasing flows and decreasing water temperatures. Preferred spawning habitat consists of low-gradient stream reaches with loose, clean gravel (Fraley and Shepard 1989, p. 141). Redds are often constructed in stream reaches fed by springs or near other sources of cold groundwater (Goetz 1989, pp. 15-16; Pratt 1992, pp. 6-7; Rieman and McIntyre 1996, p. 133). Depending on water temperature, incubation is normally 100 to 145 days (Pratt 1992, p. 1). After hatching, fry remain in the substrate, and time from egg deposition to emergence may surpass 200 days. Fry normally emerge from early April through May, depending on water temperatures and increasing stream flows (Pratt 1992, p. 1; Ratliff and Howell 1992, p. 10).

Early life stages of fish, specifically the developing embryo, require the highest inter-gravel dissolved oxygen (IGDO) levels, and are the most sensitive life stage to reduced oxygen levels. The oxygen demand of embryos depends on temperature and on stage of development, with the greatest IGDO required just prior to hatching.

A literature review conducted by the Washington Department of Ecology (WDOE 2002, p. 9) indicates that adverse effects of lower oxygen concentrations on embryo survival are magnified as temperatures increase above optimal (for incubation). Normal oxygen levels seen in rivers used by bull trout during spawning ranged from 8 to 12 mg/L (in the gravel), with corresponding instream levels of 10 to 11.5 mg/L (Stewart et al. 2007, p. 10). In addition, IGDO concentrations, water velocities in the water column, and especially the intergravel flow rate, are interrelated variables that affect the survival of incubating embryos (ODEQ 1995, Ch 2 pp. 23-24). Due to a long incubation period of 220+ days, bull trout are particularly sensitive to adequate IGDO levels. An IGDO level below 8 mg/L is likely to result in mortality of eggs, embryos, and fry.

Population Dynamics

Population Structure

Bull trout exhibit both resident and migratory life history strategies. Both resident and migratory forms may be found together, and either form may produce offspring exhibiting either resident or migratory behavior (Rieman and McIntyre 1993, p. 2). Resident bull trout complete their entire life cycle in the tributary (or nearby) streams in which they spawn and rear. The resident form tends to be smaller than the migratory form at maturity and also produces fewer eggs (Goetz 1989, p. 15). Migratory bull trout spawn in tributary streams where juvenile fish rear 1 to 4 years before migrating to either a lake (adfluvial form), river (fluvial form) (Fraley and Shepard 1989, p. 138; Goetz 1989, p. 24), or saltwater (anadromous form) to rear as subadults and to live as adults (Brenkman and Corbett 2005, entire; McPhail and Baxter 1996, p. i; WDFW et al. 1997, p. 16). Bull trout normally reach sexual maturity in 4 to 7 years and may live longer than 12 years. They are iteroparous (they spawn more than once in a lifetime). Repeat- and alternate-year spawning has been reported, although repeat-spawning frequency and post-spawning mortality

are not well documented (Fraley and Shepard 1989, p. 135; Leathe and Graham 1982, p. 95; Pratt 1992, p. 8; Rieman and McIntyre 1996, p. 133).

Bull trout are naturally migratory, which allows them to capitalize on temporally abundant food resources and larger downstream habitats. Resident forms may develop where barriers (either natural or manmade) occur or where foraging, migrating, or overwintering habitats for migratory fish are minimized (Brenkman and Corbett 2005, pp. 1075-1076; Goetz et al. 2004, p. 105). For example, multiple life history forms (e.g., resident and fluvial) and multiple migration patterns have been noted in the Grande Ronde River (Baxter 2002, pp. 96, 98-106). Parts of this river system have retained habitat conditions that allow free movement between spawning and rearing areas and the mainstem Snake River. Such multiple life history strategies help to maintain the stability and persistence of bull trout populations to environmental changes. Benefits to migratory bull trout include greater growth in the more productive waters of larger streams, lakes, and marine waters; greater fecundity resulting in increased reproductive potential; and dispersing the population across space and time so that spawning streams may be recolonized should local populations suffer a catastrophic loss (Frissell 1999, pp. 861-863; MBTSG 1998, p. 13; Rieman and McIntyre 1993, pp. 2-3). In the absence of the migratory bull trout life form, isolated populations cannot be replenished when disturbances make local habitats temporarily unsuitable. Therefore, the range of the species is diminished, and the potential for a greater reproductive contribution from larger size fish with higher fecundity is lost (Rieman and McIntyre 1993, p. 2).

Whitesel et al. (2004, p. 2) noted that although there are multiple resources that contribute to the subject, Spruell et al. (2003, entire) best summarized genetic information on bull trout population structure. Spruell et al. (2003, entire) analyzed 1,847 bull trout from 65 sampling locations, four located in three coastal drainages (Klamath, Queets, and Skagit Rivers), one in the Saskatchewan River drainage (Belly River), and 60 scattered throughout the Columbia River Basin. They concluded that there is a consistent pattern among genetic studies of bull trout, regardless of whether examining allozymes, mitochondrial DNA, or most recently microsatellite loci. Typically, the genetic pattern shows relatively little genetic variation within populations, but substantial divergence among populations. Microsatellite loci analysis supports the existence of at least three major genetically differentiated groups (or evolutionary lineages) of bull trout (Spruell et al. 2003, p. 17). They were characterized as:

1. "Coastal", including the Deschutes River and all of the Columbia River drainage downstream, as well as most coastal streams in Washington, Oregon, and British Columbia. A compelling case also exists that the Klamath Basin represents a unique evolutionary lineage within the coastal group.
2. "Snake River", which also included the John Day, Umatilla, and Walla Walla rivers. Despite close proximity of the John Day and Deschutes Rivers, a striking level of divergence between bull trout in these two systems was observed.
3. "Upper Columbia River" which includes the entire basin in Montana and northern Idaho. A tentative assignment was made by Spruell et al. (2003, p. 25) of the Saskatchewan River drainage populations (east of the continental divide), grouping them with the upper Columbia River group.

Spruell et al. (2003, p. 17) noted that within the major assemblages, populations were further subdivided, primarily at the level of major river basins. Taylor et al. (1999, entire) surveyed bull trout populations, primarily from Canada, and found a major divergence between inland and coastal populations. Costello et al. (2003, p. 328) suggested the patterns reflected the existence of two glacial refugia, consistent with the conclusions of Spruell et al. (2003, p. 26) and the biogeographic analysis of Haas and McPhail (2001, entire). Both Taylor et al. (1999, p. 1166) and Spruell et al. (2003, p. 21) concluded that the Deschutes River represented the most upstream limit of the coastal lineage in the Columbia River Basin.

More recently, the Service identified additional genetic units within the coastal and interior lineages (Ardren et al. 2011, p. 18). Based on a recommendation in the Service's 5-year review of the species' status (USFWS 2008a, p. 45), the Service reanalyzed the 27 recovery units identified in the draft bull trout recovery plan (USFWS 2002a, p. 48) by utilizing, in part, information from previous genetic studies and new information from additional analysis (Ardren et al. 2011, entire). In this examination, the Service applied relevant factors from the joint Service and NMFS Distinct Population Segment (DPS) policy (USFWS 1996, entire) and subsequently identified six draft recovery units that contain assemblages of core areas that retain genetic and ecological integrity across the range of bull trout in the coterminous United States. These six draft recovery units were used to inform designation of critical habitat for bull trout by providing a context for deciding what habitats are essential for recovery (USFWS 2010, p. 63898). The six draft recovery units identified for bull trout in the coterminous United States include: Coastal, Klamath, Mid-Columbia, Columbia Headwaters, Saint Mary, and Upper Snake. These six draft recovery units were also identified in the Service's revised recovery plan (USFWS 2015, p. vii) and designated as final recovery units.

Population Dynamics

Although bull trout are widely distributed over a large geographic area, they exhibit a patchy distribution, even in pristine habitats (Rieman and McIntyre 1993, p. 4). Increased habitat fragmentation reduces the amount of available habitat and increases isolation from other populations of the same species (Saunders et al. 1991, entire). Burkey (1989, entire) concluded that when species are isolated by fragmented habitats, low rates of population growth are typical in local populations and their probability of extinction is directly related to the degree of isolation and fragmentation. Without sufficient immigration, growth for local populations may be low and probability of extinction high (Burkey 1989, entire; Burkey 1995, entire).

Metapopulation concepts of conservation biology theory have been suggested relative to the distribution and characteristics of bull trout, although empirical evidence is relatively scant (Rieman and McIntyre 1993, p. 15; Dunham and Rieman 1999, entire; Rieman and Dunham 2000, entire). A metapopulation is an interacting network of local populations with varying frequencies of migration and gene flow among them (Meffe and Carroll 1994, pp. 189-190). For inland bull trout, metapopulation theory is likely most applicable at the watershed scale where habitat consists of discrete patches or collections of habitat capable of supporting local populations; local populations are for the most part independent and represent discrete reproductive units; and long-term, low-rate dispersal patterns among component populations influences the persistence of at least some of the local populations (Rieman and Dunham 2000, entire). Ideally, multiple local populations distributed throughout a watershed provide a

mechanism for spreading risk because the simultaneous loss of all local populations is unlikely. However, habitat alteration, primarily through the construction of impoundments, dams, and water diversions has fragmented habitats, eliminated migratory corridors, and in many cases isolated bull trout in the headwaters of tributaries (Rieman and Clayton 1997, pp. 10-12; Dunham and Rieman 1999, p. 645; Spruell et al. 1999, pp. 118-120; Rieman and Dunham 2000, p. 55).

Human-induced factors as well as natural factors affecting bull trout distribution have likely limited the expression of the metapopulation concept for bull trout to patches of habitat within the overall distribution of the species (Dunham and Rieman 1999, entire). However, despite the theoretical fit, the relatively recent and brief time period during which bull trout investigations have taken place does not provide certainty as to whether a metapopulation dynamic is occurring (e.g., a balance between local extirpations and recolonizations) across the range of the bull trout or whether the persistence of bull trout in large or closely interconnected habitat patches (Dunham and Rieman 1999, entire) is simply reflective of a general deterministic trend towards extinction of the species where the larger or interconnected patches are relics of historically wider distribution (Rieman and Dunham 2000, pp. 56-57). Recent research (Whiteley et al. 2003, entire) does, however, provide genetic evidence for the presence of a metapopulation process for bull trout, at least in the Boise River Basin of Idaho.

Habitat Characteristics

Bull trout have more specific habitat requirements than most other salmonids (Rieman and McIntyre 1993, p. 4). Habitat components that influence bull trout distribution and abundance include water temperature, cover, channel form and stability, valley form, spawning and rearing substrate, and migratory corridors (Fraley and Shepard 1989, entire; Goetz 1989, pp. 23, 25; Hoelscher and Bjornn 1989, pp. 19, 25; Howell and Buchanan 1992, pp. 30, 32; Pratt 1992, entire; Rich 1996, p. 17; Rieman and McIntyre 1993, pp. 4-6; Rieman and McIntyre 1995, entire; Sedell and Everest 1991, entire; Watson and Hillman 1997, entire). Watson and Hillman (1997, pp. 247-250) concluded that watersheds must have specific physical characteristics to provide the habitat requirements necessary for bull trout to successfully spawn and rear and that these specific characteristics are not necessarily present throughout these watersheds. Because bull trout exhibit a patchy distribution, even in pristine habitats (Rieman and McIntyre 1993, pp. 4-6), bull trout should not be expected to simultaneously occupy all available habitats.

Migratory corridors link seasonal habitats for all bull trout life histories. The ability to migrate is important to the persistence of bull trout (Rieman and McIntyre 1993, p. 2). Migrations facilitate gene flow among local populations when individuals from different local populations interbreed or stray to nonnatal streams. Local populations that are extirpated by catastrophic events may also become reestablished by bull trout migrants. However, it is important to note that the genetic structuring of bull trout indicates there is limited gene flow among bull trout populations, which may encourage local adaptation within individual populations, and that reestablishment of extirpated populations may take a long time (Rieman and McIntyre 1993, p. 2; Spruell et al. 1999, entire). Migration also allows bull trout to access more abundant or larger prey, which facilitates growth and reproduction. Additional benefits of migration and its relationship to foraging are discussed below under "Diet."

Cold water temperatures play an important role in determining bull trout habitat quality, as these fish are primarily found in colder streams, and spawning habitats are generally characterized by temperatures that drop below 9 °C in the fall (Fraley and Shepard 1989, p. 137; Pratt 1992, p. 5; Rieman and McIntyre 1993, p. 2).

Thermal requirements for bull trout appear to differ at different life stages. Spawning areas are often associated with cold-water springs, groundwater infiltration, and the coldest streams in a given watershed (Pratt 1992, pp 7-8; Rieman and McIntyre 1993, p. 7). Optimum incubation temperatures for bull trout eggs range from 2 °C to 6 °C whereas optimum water temperatures for rearing range from about 6 °C to 10 °C (Buchanan and Gregory 1997, p. 4; Goetz 1989, p. 22). In Granite Creek, Idaho, Bonneau and Scarnecchia (1996, entire) observed that juvenile bull trout selected the coldest water available in a plunge pool, 8 °C to 9 °C, within a temperature gradient of 8 °C to 15 °C. In a landscape study relating bull trout distribution to maximum water temperatures, Dunham et al. (2003, p. 900) found that the probability of juvenile bull trout occurrence does not become high (i.e., greater than 0.75) until maximum temperatures decline to 11 °C to 12 °C.

Although bull trout are found primarily in cold streams, occasionally these fish are found in larger, warmer river systems throughout the Columbia River basin (Buchanan and Gregory 1997, p. 2; Fraley and Shepard 1989, pp. 133, 135; Rieman and McIntyre 1993, pp. 3-4; Rieman and McIntyre 1995, p. 287). Availability and proximity of cold water patches and food productivity can influence bull trout ability to survive in warmer rivers (Myrick 2002, pp. 6 and 13).

All life history stages of bull trout are associated with complex forms of cover, including large woody debris, undercut banks, boulders, and pools (Fraley and Shepard 1989, p. 137; Goetz 1989, p. 19; Hoelscher and Bjornn 1989, p. 38; Pratt 1992, entire; Rich 1996, pp. 4-5; Sedell and Everest 1991, entire; Sexauer and James 1997, entire; Thomas 1992, pp. 4-6; Watson and Hillman 1997, p. 238). Maintaining bull trout habitat requires natural stability of stream channels and maintenance of natural flow patterns (Rieman and McIntyre 1993, pp. 5-6). Juvenile and adult bull trout frequently inhabit side channels, stream margins, and pools with suitable cover (Sexauer and James 1997, p. 364). These areas are sensitive to activities that directly or indirectly affect stream channel stability and alter natural flow patterns. For example, altered stream flow in the fall may disrupt bull trout during the spawning period, and channel instability may decrease survival of eggs and young juveniles in the gravel from winter through spring (Fraley and Shepard 1989, p. 141; Pratt 1992, p. 6; Pratt and Huston 1993, p. 70). Pratt (1992, p. 6) indicated that increases in fine sediment reduce egg survival and emergence.

Diet

Bull trout are opportunistic feeders, with food habits primarily a function of size and life-history strategy. Fish growth depends on the quantity and quality of food that is eaten, and as fish grow their foraging strategy changes as their food changes, in quantity, size, or other characteristics (Quinn 2005, pp. 195-200). Resident and juvenile migratory bull trout prey on terrestrial and aquatic insects, macrozooplankton, and small fish (Boag 1987, p. 58; Donald and Alger 1993, pp. 242-243; Goetz 1989, pp. 33-34). Subadult and adult migratory bull trout feed on various fish species (Donald and Alger 1993, pp. 241-243; Fraley and Shepard 1989, pp. 135, 138; Leathe and Graham 1982, pp. 13, 50-56). Bull trout of all sizes other than fry have been found to eat fish

half their length (Beauchamp and VanTassell 2001, p. 204). In nearshore marine areas of western Washington, bull trout feed on Pacific herring (*Clupea pallasi*), Pacific sand lance (*Ammodytes hexapterus*), and surf smelt (*Hypomesus pretiosus*) (Goetz et al. 2004, p. 105; WDFW et al. 1997, p. 23).

Bull trout migration and life history strategies are closely related to their feeding and foraging strategies. Migration allows bull trout to access optimal foraging areas and exploit a wider variety of prey resources. For example, in the Skagit River system, anadromous bull trout make migrations as long as 121 miles between marine foraging areas in Puget Sound and headwater spawning grounds, foraging on salmon eggs and juvenile salmon along their migration route (WDFW et al. 1997, p. 25). Anadromous bull trout also use marine waters as migration corridors to reach seasonal habitats in non-natal watersheds to forage and possibly overwinter (Brenkman and Corbett 2005, pp. 1078-1079; Goetz et al. 2004, entire).

Status and Distribution

Distribution and Demography

The historical range of bull trout includes major river basins in the Pacific Northwest at about 41 to 60 degrees North latitude, from the southern limits in the McCloud River in northern California and the Jarbidge River in Nevada to the headwaters of the Yukon River in the Northwest Territories, Canada (Cavender 1978, pp. 165-166; Bond 1992, p. 2). To the west, the bull trout's range includes Puget Sound, various coastal rivers of British Columbia, Canada, and southeast Alaska (Bond 1992, p. 2). Bull trout occur in portions of the Columbia River and tributaries within the basin, including its headwaters in Montana and Canada. Bull trout also occur in the Klamath River basin of south-central Oregon. East of the Continental Divide, bull trout are found in the headwaters of the Saskatchewan River in Alberta and Montana and in the MacKenzie River system in Alberta and British Columbia, Canada (Cavender 1978, pp. 165-166; Brewin et al. 1997, entire).

Each of the following recovery units (below) is necessary to maintain the bull trout's distribution, as well as its genetic and phenotypic diversity, all of which are important to ensure the species' resilience to changing environmental conditions. No new local populations have been identified and no local populations have been lost since listing.

Coastal Recovery Unit

The Coastal Recovery Unit is located within western Oregon and Washington. Major geographic regions include the Olympic Peninsula, Puget Sound, and Lower Columbia River basins. The Olympic Peninsula and Puget Sound geographic regions also include their associated marine waters (Puget Sound, Hood Canal, Strait of Juan de Fuca, and Pacific Coast), which are critical in supporting the anadromous[2] life history form, unique to the Coastal Recovery Unit. The Coastal Recovery Unit is also the only unit that overlaps with the distribution of Dolly Varden (*Salvelinus malma*) (Ardren *et al.* 2011), another native char species that looks very similar to the bull trout (Haas and McPhail 1991). The two species have likely had some level of historic introgression in this part of their range (Redenbach and Taylor 2002). The Lower Columbia

[2] ı Anadromous: Life history pattern of spawning and rearing in fresh water and migrating to salt water areas to mature.

River major geographic region includes the lower mainstem Columbia River, an important migratory waterway essential for providing habitat and population connectivity within this region. In the Coastal Recovery Unit, there are 21 existing bull trout core areas which have been designated, including the recently reintroduced Clackamas River population, and 4 core areas have been identified that could be re-established. Core areas within the recovery unit are distributed among these three major geographic regions (Puget Sound also includes one core area that is actually part of the lower Fraser River system in British Columbia, Canada) (USFWS 2015a, p. A-1).

The current demographic status of bull trout in the Coastal Recovery Unit is variable across the unit. Populations in the Puget Sound region generally tend to have better demographic status, followed by the Olympic Peninsula, and finally the Lower Columbia River region. However, population strongholds do exist across the three regions. The Lower Skagit River and Upper Skagit River core areas in the Puget Sound region likely contain two of the most abundant bull trout populations with some of the most intact habitat within this recovery unit. The Lower Deschutes River core area in the Lower Columbia River region also contains a very abundant bull trout population and has been used as a donor stock for re-establishing the Clackamas River population (USFWS 2015a, p. A-6).

Puget Sound Region

In the Puget Sound region, bull trout populations are concentrated along the eastern side of Puget Sound with most core areas concentrated in central and northern Puget Sound.

Although the Chilliwack River core area is considered part of this region, it is technically connected to the Fraser River system and is transboundary with British Columbia making its distribution unique within the region. Most core areas support a mix of anadromous and fluvial life history forms, with at least two core areas containing a natural adfluvial life history (Chilliwack River core area [Chilliwack Lake] and Chester Morse Lake core area). Overall demographic status of core areas generally improves as you move from south Puget Sound to north Puget Sound. Although comprehensive trend data are lacking, the current condition of core areas within this region are likely stable overall, although some at depressed abundances. Two core areas (Puyallup River and Stillaguamish River) contain local populations at either very low abundances (Upper Puyallup and Mowich Rivers) or that have likely become locally extirpated (Upper Deer Creek, South Fork Canyon Creek, and Greenwater River). Connectivity among and within core areas of this region is generally intact. Most core areas in this region still have significant amounts of headwater habitat within protected and relatively pristine areas (e.g., North Cascades National Park, Mount Rainier National Park, Skagit Valley Provincial Park, Manning Provincial Park, and various wilderness or recreation areas) (USFWS 2015a, p. A-7).

Olympic Peninsula Region

In the Olympic Peninsula region, distribution of core areas is somewhat disjunct, with only one located on the west side of Hood Canal on the eastern side of the peninsula, two along the Strait of Juan de Fuca on the northern side of the peninsula, and three along the Pacific Coast on the western side of the peninsula. Most core areas support a mix of anadromous and fluvial life history forms, with at least one core area also supporting a natural adfluvial life history (Quinault River core area [Quinault Lake]). Demographic status of core areas is poorest in Hood Canal and

Strait of Juan de Fuca, while core areas along the Pacific Coast of Washington likely have the best demographic status in this region. The connectivity between core areas in these disjunct regions is believed to be naturally low due to the geographic distance between them.

Internal connectivity is currently poor within the Skokomish River core area (Hood Canal) and is being restored in the Elwha River core area (Strait of Juan de Fuca). Most core areas in this region still have their headwater habitats within relatively protected areas (Olympic National Park and wilderness areas) (USFWS 2015a, p. A-7).

Lower Columbia River Region

In the Lower Columbia River region, the majority of core areas are distributed along the Cascade Crest on the Oregon side of the Columbia River. Only two of the seven core areas in this region are in Washington. Most core areas in the region historically supported a fluvial life history form, but many are now adfluvial due to reservoir construction. However, there is at least one core area supporting a natural adfluvial life history (Odell Lake) and one supporting a natural, isolated, resident4 life history (Klickitat River [West Fork Klickitat]). Status is highly variable across this region, with one relative stronghold (Lower Deschutes core area) existing on the Oregon side of the Columbia River. The Lower Columbia River region also contains three watersheds (North Santiam River, Upper Deschutes River, and White Salmon River) that could potentially become re-established core areas within the Coastal Recovery Unit. Although the South Santiam River has been identified as a historic core area, there remains uncertainty as to whether or not historical observations of bull trout represented a self-sustaining population. Current habitat conditions in the South Santiam River are thought to be unable to support bull trout spawning and rearing. Adult abundances within the majority of core areas in this region are relatively low, generally 300 or fewer individuals.

Most core populations in this region are not only isolated from one another due to dams or natural barriers, but they are internally fragmented as a result of manmade barriers. Local populations are often disconnected from one another or from potential foraging habitat. In the Coastal Recovery Unit, adult abundance may be lowest in the Hood River and Odell Lake core areas, which each contain fewer than 100 adults. Bull trout were reintroduced in the Middle Fork Willamette River in 1990 above Hills Creek Reservoir. Successful reproduction was first documented in 2006, and has occurred each year since (USFWS 2015a, p. A-8). Natural reproducing populations of bull trout are present in the McKenzie River basin (USFWS 2008d, pp. 65-67). Bull trout were more recently reintroduced into the Clackamas River basin in the summer of 2011 after an extensive feasibility analysis (Shively et al. 2007, Hudson et al. 2015). Bull trout from the Lower Deschutes core area are being utilized for this reintroduction effort (USFWS 2015a, p. A-8).

Klamath Recovery Unit

Bull trout in the Klamath Recovery Unit have been isolated from other bull trout populations for the past 10,000 years and are recognized as evolutionarily and genetically distinct (Minckley *et al.* 1986; Leary *et al.* 1993; Whitesel *et al.* 2004; USFWS 2008a; Ardren *et al.* 2011). As such, there is no opportunity for bull trout in another recovery unit to naturally re- colonize the Klamath Recovery Unit if it were to become extirpated. The Klamath Recovery Unit lies at the southern edge of the species range and occurs in an arid portion of the range of bull trout.

Bull trout were once widespread within the Klamath River basin (Gilbert 1897; Dambacher *et al.* 1992; Ziller 1992; USFWS 2002b), but habitat degradation and fragmentation, past and present land use practices, agricultural water diversions, and past fisheries management practices have greatly reduced their distribution. Bull trout abundance also has been severely reduced, and the remaining populations are highly fragmented and vulnerable to natural or manmade factors that place them at a high risk of extirpation (USFWS 2002b). The presence of nonnative brook trout (*Salvelinus fontinalis*), which compete and hybridize with bull trout, is a particular threat to bull trout persistence throughout the Klamath Recovery Unit (USFWS 2015b, pp. B-3-4).

Upper Klamath Lake Core Area

The Upper Klamath Lake core area comprises two bull trout local populations (Sun Creek and Threemile Creek). These local populations likely face an increased risk of extirpation because they are isolated and not interconnected with each other. Extirpation of other local populations in the Upper Klamath Lake core area has occurred in recent times (1970s). Populations in this core area are genetically distinct from those in the other two core areas in the Klamath Recovery Unit (USFWS 2008b), and in comparison, genetic variation within this core area is lowest. The two local populations have been isolated by habitat fragmentation and have experienced population bottlenecks. As such, currently unoccupied habitat is needed to restore connectivity between the two local populations and to establish additional populations. This unoccupied habitat includes canals, which now provide the only means of connectivity as migratory corridors. Providing full volitional connectivity for bull trout, however, also introduces the risk of invasion by brook trout, which are abundant in this core area.

Bull trout in the Upper Klamath Lake core area formerly occupied Annie Creek, Sevenmile Creek, Cherry Creek, and Fort Creek, but are now extirpated from these locations. The last remaining local populations, Sun Creek and Threemile Creek, have received focused attention. Brook trout have been removed from bull trout occupied reaches, and these reaches have been intentionally isolated to prevent brook trout reinvasion. As such, over the past few generations these populations have become stable and have increased in distribution and abundance. In 1996, the Threemile Creek population had approximately 50 fish that occupied a 1.4-km (0.9-mile) reach (USFWS 2002b). In 2012, a mark-resight population estimate was completed in Threemile Creek, which indicated an abundance of 577 (95 percent confidence interval = 475 to 679) age-1+ fish (ODFW 2012). In addition, the length of the distribution of bull trout in Threemile Creek had increased to 2.7 km (1.7 miles) by 2012 (USFWS unpublished data). Between 1989 and 2010, bull trout abundance in Sun Creek increased approximately tenfold (from approximately 133 to 1,606 age-1+ fish) and distribution increased from approximately 1.9 km (1.2 miles) to 11.2 km (7.0 miles) (Buktenica *et al.* 2013) (USFWS 2015b, p. B-5)

Sycan River Core Area

The Sycan River core area is comprised of one local population, Long Creek. Long Creek likely faces greater risk of extirpation because it is the only remaining local population due to extirpation of all other historic local populations. Bull trout previously occupied Calahan Creek, Coyote Creek, and the Sycan River, but are now extirpated from these locations (Light *et al.* 1996). This core area's local population is genetically distinct from those in the other two core areas (USFWS 2008b). This core area also is essential for recovery because bull trout in this core

area exhibit both resident[3] and fluvial life histories, which are important for representing diverse life history expression in the Klamath Recovery Unit. Migratory bull trout are able to grow larger than their resident counterparts, resulting in greater fecundity and higher reproductive potential (Rieman and McIntyre 1993). Migratory life history forms also have been shown to be important for population persistence and resilience (Dunham *et al.* 2008).

The last remaining population (Long Creek) has received focused attention in an effort to ensure it is not also extirpated. In 2006, two weirs were removed from Long Creek, which increased the amount of occupied foraging, migratory, and overwintering (FMO) habitat by 3.2 km (2.0 miles). Bull trout currently occupy approximately 3.5 km (2.2 mi) of spawning/rearing habitat, including a portion of an unnamed tributary to upper Long Creek, and seasonally use 25.9 km (16.1 mi) of FMO habitat. Brook trout also inhabit Long Creek and have been the focus of periodic removal efforts. No recent statistically rigorous population estimate has been completed for Long Creek; however, the 2002 Draft Bull Trout Recovery Plan reported a population estimate of 842 individuals (USFWS 2002b). Currently unoccupied habitat is needed to establish additional local populations, although brook trout are widespread in this core area and their management will need to be considered in future recovery efforts. In 2014, the Klamath Falls Fish and Wildlife Office of the U.S. Fish and Wildlife Service (Service) established an agreement with the U.S. Geological Survey to undertake a structured decision making process to assist with recovery planning of bull trout populations in the Sycan River core area (USFWS 2015b, p. B-6).

Upper Sprague River Core Area

The Upper Sprague River core area comprises five bull trout local populations, placing the core area at an intermediate risk of extinction. The five local populations include Boulder Creek, Dixon Creek, Deming Creek, Leonard Creek, and Brownsworth Creek. These local populations may face a higher risk of extirpation because not all are interconnected. Bull trout local populations in this core area are genetically distinct from those in the other two Klamath Recovery Unit core areas (USFWS 2008b). Migratory bull trout have occasionally been observed in the North Fork Sprague River (USFWS 2002b). Therefore, this core area also is essential for recovery in that bull trout here exhibit a resident life history and likely a fluvial life history, which are important for conserving diverse life history expression in the Klamath Recovery Unit as discussed above for the Sycan River core area.

The Upper Sprague River core area population of bull trout has experienced a decline from historic levels, although less is known about historic occupancy in this core area. Bull trout are reported to have historically occupied the South Fork Sprague River, but are now extirpated from this location (Buchanan *et al.* 1997). The remaining five populations have received focused attention. Although brown trout (*Salmo trutta*) co-occur with bull trout and exist in adjacent habitats, brook trout do not overlap with existing bull trout populations. Efforts have been made to increase connectivity of existing bull trout populations by replacing culverts that create barriers. Thus, over the past few generations, these populations have likely been stable and increased in distribution. Population abundance has been estimated recently for Boulder Creek (372 + 62 percent; Hartill and Jacobs 2007), Dixon Creek (20 + 60 percent; Hartill and Jacobs 2007), Deming Creek (1,316 + 342; Moore 2006), and Leonard Creek (363 + 37 percent; Hartill and Jacobs 2007). No statistically rigorous population estimate has been completed for the

[3] Resident: Life history pattern of residing in tributary streams for the fish's entire life without migrating.

Brownsworth Creek local population; however, the 2002 Draft Bull Trout Recovery Plan reported a population estimate of 964 individuals (USFWS 2002b). Additional local populations need to be established in currently unoccupied habitat within the Upper Sprague River core area, although brook trout are widespread in this core area and will need to be considered in future recovery efforts (USFWS 2015b, p. B-7).

Mid-Columbia Recovery Unit
The Mid-Columbia RU comprises 24 bull trout core areas, as well as 2 historically occupied core areas and 1 research needs area. The Mid-C RU is recognized as an area where bull trout have co-evolved with salmon, steelhead, lamprey, and other fish populations. Reduced fish numbers due to historic overfishing and land management changes have caused changes in nutrient abundance for resident migratory fish like the bull trout. The recovery unit is located within eastern Washington, eastern Oregon, and portions of central Idaho. Major drainages include the Methow River, Wenatchee River, Yakima River, John Day River, Umatilla River, Walla Walla River, Grande Ronde River, Imnaha River, Clearwater River, and smaller drainages along the Snake River and Columbia River USFWS 2015c, p. C-1).

The Mid-Columbia RU can be divided into four geographic regions the Lower Mid-Columbia, which includes all core areas that flow into the Columbia River below its confluence with the Snake River; 2) the Upper Mid-Columbia, which includes all core areas that flow into the Columbia River above its confluence with the Snake River; 3) the Lower Snake, which includes all core areas that flow into the Snake River between its confluence with the Columbia River and Hells Canyon Dam; and 4) the Mid-Snake, which includes all core areas in the Mid-C RU that flow into the Snake River above Hells Canyon Dam. These geographic regions are composed of neighboring core areas that share similar bull trout genetic, geographic (hydrographic), and/or habitat characteristics. Conserving bull trout in geographic regions allows for the maintenance of broad representation of genetic diversity, provides neighboring core areas with potential source populations in the event of local extirpations, and provides a broad array of options among neighboring core areas to contribute recovery under uncertain environmental change USFWS 2015c, pp. C-1-2).

The current demographic status of bull trout in the Mid-Columbia Recovery Unit is highly variable at both the RU and geographic region scale. Some core areas, such as the Umatilla, Asotin, and Powder Rivers, contain populations so depressed they are likely suffering from the deleterious effects of small population size. Conversely, strongholds do exist within the recovery unit, predominantly in the Lower Snake geographic area. Populations in the Imnaha, Little Minam, Clearwater, and Wenaha Rivers are likely some of the most abundant. These populations are all completely or partially within the bounds of protected wilderness areas and have some of the most intact habitat in the recovery unit. Status in some core areas is relatively unknown, but all indications in these core areas suggest population trends are declining, particularly in the core areas of the John Day Basin (USFWS 2015c, p. C-5).

Lower Mid-Columbia Region
In the Lower Mid-Columbia Region, core areas are distributed along the western portion of the Blue Mountains in Oregon and Washington. Only one of the six core areas is located completely in Washington. Demographic status is highly variable throughout the region. Status is the poorest

in the Umatilla and Middle Fork John Day Core Areas. However, the Walla Walla River core area contains nearly pristine habitats in the headwater spawning areas and supports the most abundant populations in the region. Most core areas support both a resident and fluvial life history; however, recent evidence suggests a significant decline in the resident and fluvial life history in the Umatilla River and John Day core areas respectively. Connectivity between the core areas of the Lower Mid-Columbia Region is unlikely given conditions in the connecting FMO habitats. Connection between the Umatilla, Walla Walla and Touchet core areas is uncommon but has been documented, and connectivity is possible between core areas in the John Day Basin. Connectivity between the John Day core areas and Umatilla/Walla Walla/Touchet core areas is unlikely (USFWS 2015c, pp. C-5-6).

Upper Mid-Columbia Region
In the Upper Mid-Columbia Region, core areas are distributed along the eastern side of the Cascade Mountains in Central Washington. This area contains four core areas (Yakima, Wenatchee, Entiat, and Methow), the Lake Chelan historic core area, and the Chelan River, Okanogan River, and Columbia River FMO areas. The core area populations are generally considered migratory, though they currently express both migratory (fluvial and adfluvial) and resident forms. Residents are located both above and below natural barriers (*i.e.*, Early Winters Creek above a natural falls; and Ahtanum in the Yakima likely due to long lack of connectivity from irrigation withdrawal). In terms of uniqueness and connectivity, the genetics baseline, radio-telemetry, and PIT tag studies identified unique local populations in all core areas. Movement patterns within the core areas; between the lower river, lakes, and other core areas; and between the Chelan, Okanogan, and Columbia River FMO occurs regularly for some of the Wenatchee, Entiat, and Methow core area populations. This type of connectivity has been displayed by one or more fish, typically in non-spawning movements within FMO. More recently, connectivity has been observed between the Entiat and Yakima core areas by a juvenile bull trout tagged in the Entiat moving in to the Yakima at Prosser Dam and returning at an adult size back to the Entiat. Genetics baselines identify unique populations in all four core areas USFWS 2015c, p. C-6).

The demographic status is variable in the Upper-Mid Columbia region and ranges from good to very poor. The U.S. Fish and Wildlife Service (Service) 2008 5-year Review and Conservation Status Assessment described the Methow and Yakima at risk, with a rapidly declining trend. The Entiat was listed at risk with a stable trend, and the Wenatchee as having a potential risk, and with a stable trend. Currently, the Entiat is considered to be declining rapidly due to much reduced redd counts. The Wenatchee is able to exhibit all freshwater life histories with connectivity to Lake Wenatchee, the Wenatchee River and all its local populations, and to the Columbia River and/or other core areas in the region. In the Yakima core area some populations exhibit life history forms different from what they were historically. Migration between local populations and to and from spawning habitat is generally prevented or impeded by headwater storage dams on irrigation reservoirs, connectivity between tributaries and reservoirs, and within lower portions of spawning and rearing habitat and the mainstem Yakima River due to changed flow patterns, low instream flows, high water temperatures, and other habitat impediments. Currently, the connectivity in the Yakima Core area is truncated to the degree that not all populations are able to contribute gene flow to a functional metapopulation (USFWS 2015c, pp. C-6-7)

Lower Snake Region

Demographic status is variable within the Lower Snake Region. Although trend data are lacking, several core areas in the Grande Ronde Basin and the Imnaha core area are thought to be stable. The upper Grande Ronde Core Area is the exception where population abundance is considered depressed. Wenaha, Little Minam, and Imnaha are strongholds (as mentioned above), as are most core areas in the Clearwater River basin. Most core areas contain populations that express both a resident and fluvial life history strategy. There is potential that some bull trout in the upper Wallowa River are adfluvial. There is potential for connectivity between core areas in the Grande Ronde basin, however conditions in FMO are limiting (USFWS 2015c, p. C-7).

Middle Snake Region

In the Middle Snake Region, core areas are distributed along both sides of the Snake River above Hells Canyon Dam. The Powder River and Pine Creek basins are in Oregon and Indian Creek and Wildhorse Creek are on the Idaho side of the Snake River. Demographic status of the core areas is poorest in the Powder River Core Area where populations are highly fragmented and severely depressed. The East Pine Creek population in the Pine-Indian- Wildhorse core area is likely the most abundant within the region. Populations in both core areas primarily express a resident life history strategy; however, some evidence suggests a migratory life history still exists in the Pine Creek-Indian-Wildhorse core area. Connectivity is severely impaired in the Middle Snake Region. Dams, diversions and temperature barriers prevent movement among populations and between core areas. Brownlee Dam isolates bull trout in Wildhorse Creek from other populations (USFWS 2015c, p. C-7).

Columbia Headwaters Recovery Unit

The Columbia Headwaters Recovery Unit (CHRU) includes western Montana, northern Idaho, and the northeastern corner of Washington. Major drainages include the Clark Fork River basin and its Flathead River contribution, the Kootenai River basin, and the Coeur d'Alene Lake basin. In this implementation plan for the CHRU we have slightly reorganized the structure from the 2002 Draft Recovery Plan, based on latest available science and fish passage improvements that have rejoined previously fragmented habitats. We now identify 35 bull trout core areas (compared to 47 in 2002) for this recovery unit. Fifteen of the 35 are referred to as "complex" core areas as they represent large interconnected habitats, each containing multiple spawning streams considered to host separate and largely genetically identifiable local populations. The 15 complex core areas contain the majority of individual bull trout and the bulk of the designated critical habitat (USFWS 2010).

However, somewhat unique to this recovery unit is the additional presence of 20 smaller core areas, each represented by a single local population. These "simple" core areas are found in remote glaciated headwater basins, often in Glacier National Park or federally-designated wilderness areas, but occasionally also in headwater valley bottoms. Many simple core areas are upstream of waterfalls or other natural barriers to fish migration. In these simple core areas bull trout have apparently persisted for thousands of years despite small populations and isolated existence. As such, simple core areas meet the criteria for core area designation and continue to be valued for their uniqueness, despite limitations of size and scope. Collectively, the 20 simple core areas contain less than 3 percent of the total bull trout core area habitat in the CHRU, but represent significant genetic and life history diversity (Meeuwig *et al.* 2010). Throughout this

recovery unit implementation plan, we often separate our analyses to distinguish between complex and simple core areas, both in respect to threats as well as recovery actions (USFWS 2015d, pp. D-1-2).

In order to effectively manage the RUIP structure in this large and diverse landscape, the core areas have been separated into the following five natural geographic assemblages.

Upper Clark Fork Geographic Region
Starting at the Clark Fork River headwaters, the *Upper Clark Fork Geographic Region* comprises seven complex core areas, each of which occupies one or more major watersheds contributing to the Clark Fork basin (*i.e.*, Upper Clark Fork River, Rock Creek, Blackfoot River, Clearwater River and Lakes, Bitterroot River, West Fork Bitterroot River, and Middle Clark Fork River core areas) (USFWS 2015d, p. D-2).

Lower Clark Fork Geographic Region
The seven headwater core areas flow into the *Lower Clark Fork Geographic Region*, which comprises two complex core areas, Lake Pend Oreille and Priest Lake. Because of the systematic and jurisdictional complexity (three States and a Tribal entity) and the current degree of migratory fragmentation caused by five mainstem dams, the threats and recovery actions in the Lake Pend Oreille (LPO) core area are very complex and are described in three parts. LPO-A is upstream of Cabinet Gorge Dam, almost entirely in Montana, and includes the mainstem Clark Fork River upstream to the confluence of the Flathead River as well as the portions of the lower Flathead River (*e.g.*, Jocko River) on the Flathead Indian Reservation. LPO-B is the Pend Oreille lake basin proper and its tributaries, extending between Albeni Falls Dam downstream from the outlet of Lake Pend Oreille and Cabinet Gorge Dam just upstream of the lake; almost entirely in Idaho. LPO-C is the lower basin (*i.e.*, lower Pend Oreille River), downstream of Albeni Falls Dam to Boundary Dam (1 mile upstream from the Canadian border) and bisected by Box Canyon Dam; including portions of Idaho, eastern Washington, and the Kalispel Reservation (USFWS 2015d, p. D-2).

Historically, and for current purposes of bull trout recovery, migratory connectivity among these separate fragments into a single entity remains a primary objective.

Flathead Geographic Region
The *Flathead Geographic Region* includes a major portion of northwestern Montana upstream of Kerr Dam on the outlet of Flathead Lake. The complex core area of Flathead Lake is the hub of this area, but other complex core areas isolated by dams are Hungry Horse Reservoir (formerly South Fork Flathead River) and Swan Lake. Within the glaciated basins of the Flathead River headwaters are 19 simple core areas, many of which lie in Glacier National Park or the Bob Marshall and Great Bear Wilderness areas and some of which are isolated by natural barriers or other features (USFWS 2015d, p. D-2).

Kootenai Geographic Region
To the northwest of the Flathead, in an entirely separate watershed, lies the *Kootenai Geographic Region*. The Kootenai is a uniquely patterned river system that originates in southeastern British Columbia, Canada. It dips, in a horseshoe configuration, into northwest Montana and north Idaho

before turning north again to re-enter British Columbia and eventually join the Columbia River headwaters in British Columbia. The *Kootenai Geographic Region* contains two complex core areas (Lake Koocanusa and the Kootenai River) bisected since the 1970's by Libby Dam, and also a single naturally isolated simple core area (Bull Lake). Bull trout in both of the complex core areas retain strong migratory connections to populations in British Columbia (USFWS 2015d, p. D-3).

Coeur d'Alene Geographic Region

Finally, the *Coeur d'Alene Geographic Region* consists of a single, large complex core area centered on Coeur d'Alene Lake. It is grouped into the CHRU for purposes of physical and ecological similarity (adfluvial bull trout life history and nonanadromous linkage) rather than due to watershed connectivity with the rest of the CHRU, as it flows into the mid-Columbia River far downstream of the Clark Fork and Kootenai systems (USFWS 2015d, p. D-3).

Upper Snake Recovery Unit

The Upper Snake Recovery Unit includes portions of central Idaho, northern Nevada, and eastern Oregon. Major drainages include the Salmon River, Malheur River, Jarbidge River, Little Lost River, Boise River, Payette River, and the Weiser River. The Upper Snake Recovery Unit contains 22 bull trout core areas within 7 geographic regions or major watersheds: Salmon River (10 core areas, 123 local populations), Boise River (2 core areas, 29 local populations), Payette River (5 core areas, 25 local populations), Little Lost River (1 core area, 10 local populations), Malheur River (2 core areas, 8 local populations), Jarbidge River (1 core area, 6 local populations), and Weiser River (1 core area, 5 local populations). The Upper Snake Recovery Unit includes a total of 206 local populations, with almost 60 percent being present in the Salmon River watershed (USFWS 2015e, p. E-1).

Three major bull trout life history expressions are present in the Upper Snake Recovery Unit, adfluvial[4], fluvial[5], and resident populations. Large areas of intact habitat exist primarily in the Salmon drainage, as this is the only drainage in the Upper Snake Recovery Unit that still flows directly into the Snake River; most other drainages no longer have direct connectivity due to irrigation uses or instream barriers. Bull trout in the Salmon basin share a genetic past with bull trout elsewhere in the Upper Snake Recovery Unit. Historically, the Upper Snake Recovery Unit is believed to have largely supported the fluvial life history form; however, many core areas are now isolated or have become fragmented watersheds, resulting in replacement of the fluvial life history with resident or adfluvial forms. The Weiser River, Squaw Creek, Pahsimeroi River, and North Fork Payette River core areas contain only resident populations of bull trout (USFWS 2015e, pp. E-1-2).

Salmon River

The Salmon River basin represents one of the few basins that are still free-flowing down to the Snake River. The core areas in the Salmon River basin do not have any major dams and a large extent (approximately 89 percent) is federally managed, with large portions of the Middle Fork Salmon River and Middle Fork Salmon River - Chamberlain core areas occurring within the

[4] Adfluvial: Life history pattern of spawning and rearing in tributary streams and migrating to lakes or reservoirs to mature.

[5] Fluvial: Life history pattern of spawning and rearing in tributary streams and migrating to larger rivers to mature.

Frank Church River of No Return Wilderness. Most core areas in the Salmon River basin contain large populations with many occupied stream segments. The Salmon River basin contains 10 of the 22 core areas in the Upper Snake Recovery Unit and contains the majority of the occupied habitat. Over 70 percent of occupied habitat in the Upper Snake Recovery Unit occurs in the Salmon River basin as well as 123 of the 206 local populations. Connectivity between core areas in the Salmon River basin is intact; therefore it is possible for fish in the mainstem Salmon to migrate to almost any Salmon River core area or even the Snake River.

Connectivity within Salmon River basin core areas is mostly intact except for the Pahsimeroi River and portions of the Lemhi River. The Upper Salmon River, Lake Creek, and Opal Lake core areas contain adfluvial populations of bull trout, while most of the remaining core areas contain fluvial populations; only the Pahsimeroi contains strictly resident populations. Most core areas appear to have increasing or stable trends but trends are not known in the Pahsimeroi, Lake Creek, or Opal Lake core areas. The Idaho Department of Fish and Game reported trend data from 7 of the 10 core areas. This trend data indicated that populations were stable or increasing in the Upper Salmon River, Lemhi River, Middle Salmon River-Chamberlain, Little Lost River, and the South Fork Salmon River (IDFG 2005, 2008). Trends were stable or decreasing in the Little-Lower Salmon River, Middle Fork Salmon River, and the Middle Salmon River-Panther (IDFG 2005, 2008).

Boise River

In the Boise River basin, two large dams are impassable barriers to upstream fish movement: Anderson Ranch Dam on the South Fork Boise River, and Arrowrock Dam on the mainstem Boise River. Fish in Anderson Ranch Reservoir have access to the South Fork Boise River upstream of the dam. Fish in Arrowrock Reservoir have access to the North Fork Boise River, Middle Fork Boise River, and lower South Fork Boise River. The Boise River basin contains 2 of the 22 core areas in the Upper Snake Recovery Unit. The core areas in the Boise River basin account for roughly 12 percent of occupied habitat in the Upper Snake Recovery Unit and contain 29 of the 206 local populations. Approximately 90 percent of both Arrowrock and Anderson Ranch core areas are federally owned; most lands are managed by the Forest Service, with some portions occurring in designated wilderness areas. Both the Arrowrock core area and the Anderson Ranch core area are isolated from other core areas. Both core areas contain fluvial bull trout that exhibit adfluvial characteristics and numerous resident populations. The Idaho Department of Fish and Game in 2014 determined that the Anderson Ranch core area had an increasing trend while trends in the Arrowrock core area is unknown (USFWS 2015e).

Payette River

The Payette River basin contains three major dams that are impassable barriers to fish: Deadwood Dam on the Deadwood River, Cascade Dam on the North Fork Payette River, and Black Canyon Reservoir on the Payette River. Only the Upper South Fork Payette River and the Middle Fork Payette River still have connectivity, the remaining core areas are isolated from each other due to dams. Both fluvial and adfluvial life history expression are still present in the Payette River basin but only resident populations are present in the Squaw Creek and North Fork Payette River core areas. The Payette River basin contains 5 of the 22 core areas and 25 of the 206 local populations in the recovery unit. Less than 9 percent of occupied habitat in the recovery unit is in this basin. Approximately 60 percent of the lands in the core areas are

federally owned and the majority is managed by the Forest Service. Trend data are lacking and the current condition of the various core areas is unknown, but there is concern due to the current isolation of three (North Fork Payette River, Squaw Creek, Deadwood River) of the five core areas; the presence of only resident local populations in two (North Fork Payette River, Squaw Creek) of the five core areas; and the relatively low numbers present in the North Fork core area (USFWS 2015e, p. E-8).

Jarbidge River

The Jarbidge River core area contains two major fish barriers along the Bruneau River: the Buckaroo diversion and C. J. Strike Reservoir. Bull trout are not known to migrate down to the Snake River. There is one core area in the basin, with populations in the Jarbidge River; this watershed does not contain any barriers. Approximately 89 percent of the Jarbidge core area is federally owned. Most lands are managed by either the Forest Service or Bureau of Land Management. A large portion of the core area is within the Bruneau-Jarbidge Wilderness area. A tracking study has documented bull trout population connectivity among many of the local populations, in particular between West Fork Jarbidge River and Pine Creek. Movement between the East and West Fork Jarbidge River has also been documented; therefore both resident and fluvial populations are present. The core area contains six local populations and 3 percent of the occupied habitat in the recovery unit. Trend data are lacking within this core area (USFWS 2015e, p. E-9).

Little Lost River

The Little Lost River basin is unique in that the watershed is within a naturally occurring hydrologic sink and has no connectivity with other drainages. A small fluvial population of bull trout may still exist, but it appears that most populations are predominantly resident populations. There is one core area in the Little Lost basin, and approximately 89 percent of it is federally owned by either the Forest Service or Bureau of Land Management. The core area contains 10 local populations and less than 3 percent of the occupied habitat in the recovery unit. The current trend condition of this core area is likely stable, with most bull trout residing in Upper Sawmill Canyon (IDFG 2014).

Malheur River

The Malheur River basin contains major dams that are impassable to fish. The largest are Warm Springs Dam, impounding Warm Springs Reservoir on the mainstem Malheur River, and Agency Valley Dam, impounding Beulah Reservoir on the North Fork Malheur. The dams result in two core areas that are isolated from each other and from other core areas. Local populations in the two core areas are limited to habitat in the upper watersheds. The Malheur River basin contains 2 of the 22 core areas and 8 of the 206 local populations in the recovery unit. Fluvial and resident populations are present in both core areas while adfluvial populations are present in the North Fork Malheur. This basin contains less than 3 percent of the occupied habitat in the recovery unit, and approximately 60 percent of lands in the two core areas are federally owned. Trend data indicates that populations are declining in both core areas (USFWS 2015e, p. E-9).

Weiser River

The Weiser River basin contains local populations that are limited to habitat in the upper watersheds. The Weiser River basin contains only a single core area that consists of 5 of the 206

local populations in the recovery unit. Local populations occur in only three stream complexes in the upper watershed: 1) Upper Hornet Creek, 2) East Fork Weiser River, and 3) Upper Little Weiser River. These local populations include only resident life histories. This basin contains less than 2 percent of the occupied habitat in the recovery unit, and approximately 44 percent of lands are federally owned. Trend data from the Idaho Department of Fish and Game indicate that the populations in the Weiser core area are increasing (IDFG 2014) but it is considered vulnerable because local populations are isolated and likely do not express migratory life histories (USFWS 2015e, p.E-10).

St. Mary Recovery Unit
The Saint Mary Recovery Unit is located in northwest Montana east of the Continental Divide and includes the U.S. portions of the Saint Mary River basin, from its headwaters to the international boundary with Canada at the 49th parallel. The watershed and the bull trout population are linked to downstream aquatic resources in southern Alberta, Canada; the U.S. portion includes headwater spawning and rearing (SR) habitat in the tributaries and a portion of the foraging, migrating, and overwintering (FMO) habitat in the mainstem of the Saint Mary River and Saint Mary lakes (Mogen and Kaeding 2001).

The Saint Mary Recovery Unit comprises four core areas; only one (Saint Mary River) is a complex core area with five described local bull trout populations (Divide, Boulder, Kennedy, Otatso, and Lee Creeks). Roughly half of the linear extent of available FMO habitat in the mainstem Saint Mary system (between Saint Mary Falls at the upstream end and the downstream Canadian border) is comprised of Saint Mary and Lower Saint Mary Lakes, with the remainder in the Saint Mary River. The other three core areas (Slide Lakes, Cracker Lake, and Red Eagle Lake) are simple core areas. Slide Lakes and Cracker Lake occur upstream of seasonal or permanent barriers and are comprised of genetically isolated single local bull trout populations, wholly within Glacier National Park, Montana. In the case of Red Eagle Lake, physical isolation does not occur, but consistent with other lakes in the adjacent Columbia Headwaters Recovery Unit, there is likely some degree of spatial separation from downstream Saint Mary Lake. As noted, the extent of isolation has been identified as a research need (USFWS 2015f, p. F-1).

Bull trout in the Saint Mary River complex core area are documented to exhibit primarily the migratory fluvial life history form (Mogen and Kaeding 2005a, 2005b), but there is doubtless some occupancy (though less well documented) of Saint Mary Lakes, suggesting a partly adfluvial adaptation. Since lake trout and northern pike are both native to the Saint Mary River system (headwaters of the South Saskatchewan River drainage draining to Hudson Bay), the conventional wisdom is that these large piscivores historically outcompeted bull trout in the lacustrine environment (Donald and Alger 1993, Martinez *et al.* 2009), resulting in a primarily fluvial niche and existence for bull trout in this system. This is an untested hypothesis and additional research into this aspect is needed (USFWS 2015f, p. F-3).

Bull trout populations in the simple core areas of the three headwater lake systems (Slide, Cracker, and Red Eagle Lakes) are, by definition, adfluvial; there are also resident life history components in portions of the Saint Mary River system such as Lower Otatso Creek (Mogen and Kaeding 2005a), further exemplifying the overall life history diversity typical of bull trout. Mogen and Kaeding (2001) reported that bull trout continue to inhabit nearly all suitable habitats

accessible to them in the Saint Mary River basin in the United States. The possible exception is portions of Divide Creek, which appears to be intermittently occupied despite a lack of permanent migratory barriers, possibly due to low population size and erratic year class production (USFWS 2015f, p. F-3).

It should be noted that bull trout are found in minor portions of two additional U.S. watersheds (Belly and Waterton rivers) that were once included in the original draft recovery plan (USFWS 2002) but are no longer considered core areas in the final recovery plan (USFWS 2015) and are not addressed in that document. In Alberta, Canada, the Saint Mary River bull trout population is considered at "high risk," while the Belly River is rated as "at risk" (ACA 2009). In the Belly River drainage, which enters the South Saskatchewan system downstream of the Saint Mary River in Alberta, some bull trout spawning is known to occur on either side of the international boundary. These waters are in the drainage immediately west of the Saint Mary River headwaters. However, the U.S. range of this population constitutes only a minor headwater migratory SR segment of an otherwise wholly Canadian population, extending less than 1 mile (0.6 km) into backcountry waters of Glacier National Park. The Belly River population is otherwise totally dependent on management within Canadian jurisdiction, with no natural migratory connection to the Saint Mary (USFWS 2015f, p. F-3).

Current status of bull trout in the Saint Mary River core area (U.S.) is considered strong (Mogen 2013). Migratory bull trout redd counts are conducted annually in the two major SR streams, Boulder and Kennedy creeks. Boulder Creek redd counts have ranged from 33 to 66 in the past decade, with the last 4 counts all 53 or higher. Kennedy Creek redd counts are less robust, ranging from 5 to 25 over the last decade, with a 2014 count of 20 (USFWS 2015f, p. F-3).

Generally, the demographic status of the Saint Mary River core area is believed to be good, with the exception of the Divide Creek local population. In this local population, there is evidence that a combination of ongoing habitat manipulation (Smillie and Ellerbroek 1991,F-5 NPS 1992) resulting in occasional historical passage issues, combined with low and erratic recruitment (DeHaan *et al.* 2011) has caused concern for the continuing existence of the local population.

While less is known about the demographic status of the three simple cores where redd counts are not conducted, all three appear to be self-sustaining and fluctuating within known historical population demographic bounds. Of the three simple core areas, demographic status in Slide Lakes and Cracker Lake appear to be functioning appropriately, but the demographic status in Red Eagle Lake is less well documented and believed to be less robust (USFWS 2015f, p. F-3).

Reasons for Listing
Bull trout distribution, abundance, and habitat quality have declined rangewide (Bond 1992, pp. 2-3; Schill 1992, p. 42; Thomas 1992, entire; Ziller 1992, entire; Rieman and McIntyre 1993, p. 1; Newton and Pribyl 1994, pp. 4-5; McPhail and Baxter 1996, p. 1). Several local extirpations have been documented, beginning in the 1950s (Rode 1990, pp. 26-32; Ratliff and Howell 1992, entire; Donald and Alger 1993, entire; Goetz 1994, p. 1; Newton and Pribyl 1994, pp. 8-9; Light et al. 1996, pp. 6-7; Buchanan et al. 1997, p. 15; WDFW 1998, pp. 2-3). Bull trout were extirpated from the southernmost portion of their historic range, the McCloud River in California, around 1975 (Rode 1990, p. 32). Bull trout have been functionally extirpated (i.e.,

few individuals may occur there but do not constitute a viable population) in the Coeur d'Alene River basin in Idaho and in the Lake Chelan and Okanogan River basins in Washington (USFWS 1998, pp. 31651-31652).

These declines result from the combined effects of habitat degradation and fragmentation, the blockage of migratory corridors; poor water quality, angler harvest and poaching, entrainment (process by which aquatic organisms are pulled through a diversion or other device) into diversion channels and dams, and introduced nonnative species. Specific land and water management activities that depress bull trout populations and degrade habitat include the effects of dams and other diversion structures, forest management practices, livestock grazing, agriculture, agricultural diversions, road construction and maintenance, mining, and urban and rural development (Beschta et al. 1987, entire; Chamberlain et al. 1991, entire; Furniss et al. 1991, entire; Meehan 1991, entire; Nehlsen et al. 1991, entire; Sedell and Everest 1991, entire; Craig and Wissmar 1993pp, 18-19; Henjum et al. 1994, pp. 5-6; McIntosh et al. 1994, entire; Wissmar et al. 1994, entire; MBTSG 1995a, p. 1; MBTSG 1995b. pp. i-ii; MBTSG 1995c, pp. i-ii; MBTSG 1995d, p. 22; MBTSG 1995e, p. i; MBTSG 1996a, p. i-ii; MBTSG 1996b, p. i; MBTSG 1996c, p. i; MBTSG 1996d, p. i; MBTSG 1996e, p. i; MBTSG 1996f, p. 11; Light et al. 1996, pp. 6-7; USDA and USDI 1995, p. 2).

Emerging Threats

Climate Change

Climate change was not addressed as a known threat when bull trout was listed. The 2015 bull trout recovery plan and RUIPs summarize the threat of climate change and acknowledges that some extant bull trout core area habitats will likely change (and may be lost) over time due to anthropogenic climate change effects, and use of best available information will ensure future conservation efforts that offer the greatest long-term benefit to sustain bull trout and their required coldwater habitats (USFWS 2015, p. vii, and pp. 17-20, USFWS 2015a-f).

Global climate change and the related warming of global climate have been well documented (IPCC 2007a, entire; ISAB 2007, entire; Combes 2003, entire). Evidence of global climate change/warming includes widespread increases in average air and ocean temperatures and accelerated melting of glaciers, and rising sea level. Given the increasing certainty that climate change is occurring and is accelerating (IPCC 2007a, p. 253; Battin et al. 2007, p. 6720), we can no longer assume that climate conditions in the future will resemble those in the past.

Patterns consistent with changes in climate have already been observed in the range of many species and in a wide range of environmental trends (ISAB 2007, entire; Hari et al. 2006, entire; Rieman et al. 2007, entire). In the northern hemisphere, the duration of ice cover over lakes and rivers has decreased by almost 20 days since the mid-1800's (Magnuson et al. 2000, p. 1743). The range of many species has shifted poleward and elevationally upward. For cold-water associated salmonids in mountainous regions, where their upper distribution is often limited by impassable barriers, an upward thermal shift in suitable habitat can result in a reduction in range, which in turn can lead to a population decline (Hari et al. 2006, entire).

In the Pacific Northwest, most models project warmer air temperatures and increases in winter precipitation and decreases in summer precipitation. Warmer temperatures will lead to more precipitation falling as rain rather than snow. As the seasonal amount of snow pack diminishes, the timing and volume of stream flow are likely to change and peak river flows are likely to increase in affected areas. Higher air temperatures are also likely to increase water temperatures (ISAB 2007, pp. 15-17). For example, stream gauge data from western Washington over the past 5 to 25 years indicate a marked increasing trend in water temperatures in most major rivers.

Climate change has the potential to profoundly alter the aquatic ecosystems upon which the bull trout depends via alterations in water yield, peak flows, and stream temperature, and an increase in the frequency and magnitude of catastrophic wildfires in adjacent terrestrial habitats (Bisson et al. 2003, pp 216-217).

All life stages of the bull trout rely on cold water. Increasing air temperatures are likely to impact the availability of suitable cold water habitat. For example, ground water temperature is generally correlated with mean annual air temperature, and has been shown to strongly influence the distribution of other chars. Ground water temperature is linked to bull trout selection of spawning sites, and has been shown to influence the survival of embryos and early juvenile rearing of bull trout (Baxter 1997, p. 82). Increases in air temperature are likely to be reflected in increases in both surface and groundwater temperatures.

Climate change is likely to affect the frequency and magnitude of fires, especially in warmer drier areas such as are found on the eastside of the Cascade Mountains. Bisson et al. (2003, pp. 216-217) note that the forest that naturally occurred in a particular area may or may not be the forest that will be responding to the fire regimes of an altered climate. In several studies related to the effect of large fires on bull trout populations, bull trout appear to have adapted to past fire disturbances through mechanisms such as dispersal and plasticity. However, as stated earlier, the future may well be different than the past and extreme fire events may have a dramatic effect on bull trout and other aquatic species, especially in the context of continued habitat loss, simplification and fragmentation of aquatic systems, and the introduction and expansion of exotic species (Bisson et al. 2003, pp. 218-219).

Migratory bull trout can be found in lakes, large rivers and marine waters. Effects of climate change on lakes are likely to impact migratory adfluvial bull trout that seasonally rely upon lakes for their greater availability of prey and access to tributaries. Climate-warming impacts to lakes will likely lead to longer periods of thermal stratification and coldwater fish such as adfluvial bull trout will be restricted to these bottom layers for greater periods of time. Deeper thermoclines resulting from climate change may further reduce the area of suitable temperatures in the bottom layers and intensify competition for food (Shuter and Meisner 1992. p. 11).
Bull trout require very cold water for spawning and incubation. Suitable spawning habitat is often found in accessible higher elevation tributaries and headwaters of rivers. However, impacts on hydrology associated with climate change are related to shifts in timing, magnitude and distribution of peak flows that are also likely to be most pronounced in these high elevation stream basins (Battin et al. 2007, p. 6720). The increased magnitude of winter peak flows in high elevation areas is likely to impact the location, timing, and success of spawning and incubation for the bull trout and Pacific salmon species. Although lower elevation river reaches are not

expected to experience as severe an impact from alterations in stream hydrology, they are unlikely to provide suitably cold temperatures for bull trout spawning, incubation and juvenile rearing.

As climate change progresses and stream temperatures warm, thermal refugia will be critical to the persistence of many bull trout populations. Thermal refugia are important for providing bull trout with patches of suitable habitat during migration through or to make feeding forays into areas with greater than optimal temperatures.

There is still a great deal of uncertainty associated with predictions relative to the timing, location, and magnitude of future climate change. It is also likely that the intensity of effects will vary by region (ISAB 2007, p 7) although the scale of that variation may exceed that of States. For example, several studies indicate that climate change has the potential to impact ecosystems in nearly all streams throughout the State of Washington (ISAB 2007, p. 13; Battin et al. 2007, p. 6722; Rieman et al. 2007, pp. 1558-1561). In streams and rivers with temperatures approaching or at the upper limit of allowable water temperatures, there is little if any likelihood that bull trout will be able to adapt to or avoid the effects of climate change/warming. There is little doubt that climate change is and will be an important factor affecting bull trout distribution. As its distribution contracts, patch size decreases and connectivity is truncated, bull trout populations that may be currently connected may face increasing isolation, which could accelerate the rate of local extinction beyond that resulting from changes in stream temperature alone (Rieman et al. 2007, pp. 1559-1560). Due to variations in land form and geographic location across the range of the bull trout, it appears that some populations face higher risks than others. Bull trout in areas with currently degraded water temperatures and/or at the southern edge of its range may already be at risk of adverse impacts from current as well as future climate change.

The ability to assign the effects of gradual global climate change to bull trout or to a specific location on the ground is beyond our technical capabilities at this time.

Conservation Needs

The 2015 recovery plan for bull trout established the primary strategy for recovery of bull trout in the coterminous United States: (1) conserve bull trout so that they are geographically widespread across representative habitats and demographically stable in six recovery units; (2) effectively manage and ameliorate the primary threats in each of six recovery units at the core area scale such that bull trout are not likely to become endangered in the foreseeable future; (3) build upon the numerous and ongoing conservation actions implemented on behalf of bull trout since their listing in 1999, and improve our understanding of how various threat factors potentially affect the species; (4) use that information to work cooperatively with our partners to design, fund, prioritize, and implement effective conservation actions in those areas that offer the greatest long-term benefit to sustain bull trout and where recovery can be achieved; and (5) apply adaptive management principles to implementing the bull trout recovery program to account for new information (USFWS 2015, p. v.).

Information presented in prior draft recovery plans published in 2002 and 2004 (USFWS 2002a, 2004, 2004a) have served to identify recovery actions across the range of the species and to

provide a framework for implementing numerous recovery actions by our partner agencies, local working groups, and others with an interest in bull trout conservation.

The 2015 recovery plan (USFWS 2015) integrates new information collected since the 1999 listing regarding bull trout life history, distribution, demographics, conservation successes, etc., and integrates and updates previous bull trout recovery planning efforts across the range of the single DPS listed under the Act.

The Service has developed a recovery approach that: (1) focuses on the identification of and effective management of known and remaining threat factors to bull trout in each core area; (2) acknowledges that some extant bull trout core area habitats will likely change (and may be lost) over time; and (3) identifies and focuses recovery actions in those areas where success is likely to meet our goal of ensuring the certainty of conservation of genetic diversity, life history features, and broad geographical representation of remaining bull trout populations so that the protections of the Act are no longer necessary (USFWS 2015, p. 45-46).

To implement the recovery strategy, the 2015 recovery plan establishes categories of recovery actions for each of the six Recovery Units (USFWS 2015, p. 50-51):

1. Protect, restore, and maintain suitable habitat conditions for bull trout.
2. Minimize demographic threats to bull trout by restoring connectivity or populations where appropriate to promote diverse life history strategies and conserve genetic diversity.
3. Prevent and reduce negative effects of nonnative fishes and other nonnative taxa on bull trout.
4. Work with partners to conduct research and monitoring to implement and evaluate bull trout recovery activities, consistent with an adaptive management approach using feedback from implemented, site-specific recovery tasks, and considering the effects of climate change.

Bull trout recovery is based on a geographical hierarchical approach. Bull trout are listed as a single DPS within the five-state area of the coterminous United States. The single DPS is subdivided into six biologically-based recover units: (1) Coastal Recovery Unit; (2) Klamath Recovery Unit; (3) Mid-Columbia Recovery Unit; (4) Upper Snake Recovery Unit; (5) Columbia Headwaters Recovery Unit; and (6) Saint Mary Recovery Unit (USFWS 2015, p. 23). A viable recovery unit should demonstrate that the three primary principles of biodiversity have been met: representation (conserving the genetic makeup of the species); resiliency (ensuring that each population is sufficiently large to withstand stochastic events); and redundancy (ensuring a sufficient number of populations to withstand catastrophic events) (USFWS 2015, p. 33).

Each of the six recovery units contain multiple bull trout core areas, 116 total, which are non-overlapping watershed-based polygons, and each core area includes one or more local populations. Currently there are 109 occupied core areas, which comprise 611 local populations (USFWS 2015, p. 3). There are also six core areas where bull trout historically occurred but are now extirpated, and one research needs area where bull trout were known to occur historically, but their current presence and use of the area are uncertain (USFWS 2015, p. 3).Core areas can

be further described as complex or simple (USFWS 2015, p. 3-4). Complex core areas contain multiple local bull trout populations, are found in large watersheds, have multiple life history forms, and have migratory connectivity between spawning and rearing habitat and foraging, migration, and overwintering habitats (FMO). Simple core areas are those that contain one bull trout local population. Simple core areas are small in scope, isolated from other core areas by natural barriers, and may contain unique genetic or life history adaptations.

A local population is a group of bull trout that spawn within a particular stream or portion of a stream system (USFWS 2015, p. 73). A local population is considered to be the smallest group of fish that is known to represent an interacting reproductive unit. For most waters where specific information is lacking, a local population may be represented by a single headwater tributary or complex of headwater tributaries. Gene flow may occur between local populations (e.g., those within a core population), but is assumed to be infrequent compared with that among individuals within a local population.

Population Units

The final recovery plan (USFWS 2015) designates six bull trout recovery units as described above. These units replace the 5 interim recovery units previously identified (USFWS 1999a). The Service will address the conservation of these final recovery units in our section 7(a)(2) analysis for proposed Federal actions. The recovery plan (USFWS 2015, identified threats and factors affecting the bull trout within these units. A detailed description of recovery implementation for each recovery unit is provided in separate recovery unit implementation plans (RUIPs)(USFWS 2015a-f), which identify conservation actions and recommendations needed for each core area, forage/ migration/ overwinter (FMO) areas, historical core areas, and research needs areas. Each of the following recovery units (below) is necessary to maintain the bull trout's distribution, as well as its genetic and phenotypic diversity, all of which are important to ensure the species' resilience to changing environmental conditions.

Coastal Recovery Unit

The coastal recovery unit implementation plan describes the threats to bull trout and the site-specific management actions necessary for recovery of the species within the unit (USFWS 2015a). The Coastal Recovery Unit is located within western Oregon and Washington. The Coastal Recovery Unit is divided into three regions: Puget Sound, Olympic Peninsula, and the Lower Columbia River Regions. This recovery unit contains 20 core areas comprising 84 local populations and a single potential local population in the historic Clackamas River core area where bull trout had been extirpated and were reintroduced in 2011, and identified four historically occupied core areas that could be re-established (USFWS 2015, pg. 47; USFWS 2015a, p. A-2). Core areas within Puget Sound and the Olympic Peninsula currently support the only anadromous local populations of bull trout. This recovery unit also contains ten shared FMO habitats which are outside core areas and allows for the continued natural population dynamics in which the core areas have evolved (USFWS 2015a, p. A-5). There are four core areas within the Coastal Recovery Unit that have been identified as current population strongholds: Lower Skagit, Upper Skagit, Quinault River, and Lower Deschutes River (USFWS 2015, p.79). These are the most stable and abundant bull trout populations in the recovery unit. The current condition of the bull trout in this recovery unit is attributed to the adverse effects of

climate change, loss of functioning estuarine and nearshore marine habitats, development and related impacts (e.g., flood control, floodplain disconnection, bank armoring, channel straightening, loss of instream habitat complexity), agriculture (e.g., diking, water control structures, draining of wetlands, channelization, and the removal of riparian vegetation, livestock grazing), fish passage (e.g., dams, culverts, instream flows) residential development, urbanization, forest management practices (e.g., timber harvest and associated road building activities), connectivity impairment, mining, and the introduction of non-native species. Conservation measures or recovery actions implemented include relicensing of major hydropower facilities that have provided upstream and downstream fish passage or complete removal of dams, land acquisition to conserve bull trout habitat, floodplain restoration, culvert removal, riparian revegetation, levee setbacks, road removal, and projects to protect and restore important nearshore marine habitats.

Klamath Recovery Unit

The Klamath recovery unit implementation plan describes the threats to bull trout and the site-specific management actions necessary for recovery of the species within the unit (USFWS 2015b). The Klamath Recovery Unit is located in southern Oregon and northwestern California. The Klamath Recovery Unit is the most significantly imperiled recovery unit, having experienced considerable extirpation and geographic contraction of local populations and declining demographic condition, and natural re-colonization is constrained by dispersal barriers and presence of nonnative brook trout (USFWS 2015, p. 39). This recovery unit currently contains three core areas and eight local populations (USFWS 2015, p. 47; USFWS 2015b, p. B-1). Nine historic local populations of bull trout have become extirpated (USFWS 2015b, p. B-1). All three core areas have been isolated from other bull trout populations for the past 10,000 years (USFWS 2015b, p. B-3. The current condition of the bull trout in this recovery unit is attributed to the adverse effects of climate change, habitat degradation and fragmentation, past and present land use practices, agricultural water diversions, nonnative species, and past fisheries management practices. Conservation measures or recovery actions implemented include removal of nonnative fish (e.g., brook trout, brown trout, and hybrids), acquiring water rights for instream flows, replacing diversion structures, installing fish screens, constructing bypass channels, installing riparian fencing, culver replacement, and habitat restoration.

Mid-Columbia Recovery Unit

The Mid-Columbia recovery unit implementation plan describes the threats to bull trout and the site-specific management actions necessary for recovery of the species within the unit (USFWS 2015c). The Mid-Columbia Recovery Unit is located within eastern Washington, eastern Oregon, and portions of central Idaho. The Mid-Columbia Recovery Unit is divided into four geographic regions: Lower Mid-Columbia, Upper Mid-Columbia, Lower Snake, and Mid-Snake Geographic Regions. This recovery unit contains 24 occupied core areas comprising 142 local populations, two historically occupied core areas, one research needs area, and seven FMO habitats (USFWS 2015, pg. 47; USFWS 2015c, p. C-1–4). The current condition of the bull trout in this recovery unit is attributed to the adverse effects of climate change, agricultural practices (e.g. irrigation, water withdrawals, livestock grazing), fish passage (e.g. dams, culverts), nonnative species, forest management practices, and mining. Conservation measures or recovery actions

implemented include road removal, channel restoration, mine reclamation, improved grazing management, removal of fish barriers, and instream flow requirements.

Columbia Headwaters Recovery Unit

The Columbia headwaters recovery unit implementation plan describes the threats to bull trout and the site-specific management actions necessary for recovery of the species within the unit (USFWS 2015d, entire). The Columbia Headwaters Recovery Unit is located in western Montana, northern Idaho, and the northeastern corner of Washington. The Columbia Headwaters Recovery Unit is divided into five geographic regions: Upper Clark Fork, Lower Clark Fork, Flathead, Kootenai, and Coeur d'Alene Geographic Regions (USFWS 2015d, pp. D-2 – D-4). This recovery unit contains 35 bull trout core areas; 15 of which are complex core areas as they represent larger interconnected habitats and 20 simple core areas as they are isolated headwater lakes with single local populations. The 20 simple core areas are each represented by a single local population, many of which may have persisted for thousands of years despite small populations and isolated existence (USFWS 2015d, p. D-1). Fish passage improvements within the recovery unit have reconnected some previously fragmented habitats (USFWS 2015d, p. D-1), while others remain fragmented. Unlike the other recovery units in Washington, Idaho and Oregon, the Columbia Headwaters Recovery Unit does not have any anadromous fish overlap. Therefore, bull trout within the Columbia Headwaters Recovery Unit do not benefit from the recovery actions for salmon (USFWS 2015d, p. D-41). The current condition of the bull trout in this recovery unit is attributed to the adverse effects of climate change, mostly historical mining and contamination by heavy metals, expanding populations of nonnative fish predators and competators, modified instream flows, migratory barriers (e.g., dams), habitat fragmentation, forest practices (e.g., logging, roads), agriculture practices (e.g. irrigation, livestock grazing), and residential development. Conservation measures or recovery actions implemented include habitat improvement, fish passage, and removal of nonnative species.

Upper Snake Recovery Unit

The Upper Snake recovery unit implementation plan describes the threats to bull trout and the site-specific management actions necessary for recovery of the species within the unit (USFWS 2015e, entire). The Upper Snake Recovery Unit is located in central Idaho, northern Nevada, and eastern Oregon. The Upper Snake Recovery Unit is divided into seven geographic regions: Salmon River, Boise River, Payette River, Little Lost River, Malheur River, Jarbidge River, and Weiser River. This recovery unit contains 22 core areas and 207 local populations (USFWS 2015, p. 47), with almost 60 percent being present in the Salmon River Region. The current condition of the bull trout in this recovery unit is attributed to the adverse effects of climate change, dams, mining, forest management practices, nonnative species, and agriculture (e.g., water diversions, grazing). Conservation measures or recovery actions implemented include instream habitat restoration, instream flow requirements, screening of irrigation diversions, and riparian restoration.

St. Mary Recovery Unit

The St. Mary recovery unit implementation plan describes the threats to bull trout and the site-specific management actions necessary for recovery of the species within the unit (USFWS 2015f). The Saint Mary Recovery Unit is located in Montana but is heavily linked to downstream resources in southern Alberta, Canada. Most of the Saskatchewan River watershed which the St. Mary flows into is located in Canada. The United States portion includes headwater spawning and rearing habitat and the upper reaches of FMO habitat. This recovery unit contains four core areas, and seven local populations (USFWS 2015f, p. F-1) in the U.S. Headwaters. The current condition of the bull trout in this recovery unit is attributed primarily to the outdated design and operations of the Saint Mary Diversion operated by the Bureau of Reclamation (e.g., entrainment, fish passage, instream flows), and, to a lesser extent habitat impacts from development and nonnative species.

Tribal Conservation Activities

Many Tribes throughout the range of the bull trout are participating on bull trout conservation working groups or recovery teams in their geographic areas of interest. Some tribes are also implementing projects which focus on bull trout or that address anadromous fish but benefit bull trout (e.g., habitat surveys, passage at dams and diversions, habitat improvement, and movement studies).

2.2.6 Chinook Salmon Critical Habitat

The NMFS designated critical habitat for Chinook salmon on September 2, 2005 (70 FR 52630). The specific geographic area includes portions of the Nooksack River, Skagit River, Sauk River, Stillaguamish River, Skykomish River, Snoqualmie River, Lake Washington, Green River, Puyallup River, White River, Nisqually River, Hamma Hamma River and other Hood Canal watersheds, the Dungeness/Elwha Watersheds, and nearshore marine areas of the Strait of Georgia, Puget Sound, Hood Canal, and the Strait of Juan de Fuca. This designation includes the stream channels within the designated stream reaches, and includes a lateral extent as defined by the ordinary high water line. In areas where the ordinary high water line is not defined the lateral extent is defined as the bank full elevation.

The designation for this ESU includes sites necessary to support one or more life stages. These areas are important for the species' overall conservation by protecting quality growth, reproduction, and feeding. The PCEs of Chinook salmon critical habitat are:

1. Freshwater spawning sites with water quantity and quality conditions and substrate that support spawning, incubation, and larval development;
2. Freshwater rearing sites with (1) water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility, (2) water quality and forage that support juvenile development, and (3) natural cover such as shade, submerged and overhanging large wood, logjams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks;

3. Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks that support juvenile and adult mobility and survival;
4. Estuarine areas free of obstruction and excessive predation with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation;
5. Nearshore marine areas free of obstruction and excessive predation with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and
6. Offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.

Of 49 subbasins reviewed in NMFS' assessment of critical habitat for the Puget Sound ESUs, nine subbasins were rated as having a medium conservation value, 12 were rated as low, and the remaining subbasins (40), where the bulk of Federal lands occur for this ESU, were rated as having a high conservation value to Chinook salmon. Factors contributing to the downward trends in this ESU are hydromorphological changes (such as diking, revetments, loss of secondary channels in floodplains, widespread blockages of streams, and changes in peak flows), degraded freshwater and marine habitat affected by agricultural activities and urbanization, and upper river tributaries widely affected by poor forest practices. Changes in habitat quantity, availability, diversity, flow, temperature, sediment load, and channel stability are common limiting factors in areas of critical habitat. The nearshore marine habitat has been extensively altered and armored by industrial and residential development near the mouths of many of Puget Sound's tributaries. A railroad runs along large portions of the eastern shoreline of Puget Sound, eliminating natural cover along the shore and natural recruitment of beach sand (SSPS 2007).

Habitat conditions that are limiting. Residential and commercial development has reduced the amount of functioning nearshore and estuarine habitat available for salmon rearing and migration (NMFS 2011b; SSPS 2007). The loss of mudflats, eelgrass meadows, and macroalgae further limits salmon foraging and rearing opportunities in nearshore and estuarine areas. Floodplain connectivity and function, channel structure and complexity, riparian areas and large wood supply, stream substrate, and water quality have also been degraded for adult spawning, embryo incubation, and rearing as a result of cumulative impacts of agriculture, forestry, and development.

2.2.7 Bocaccio Critical Habitat

Critical habitat was designated for bocaccio in 2014 under section 4(a)(3)(A) of the ESA (79 FR 68041, November 13, 2014). The specific areas designated for bocaccio include approximately 1,083.11 square miles (1,743.10 sq. km) of deep water (< 98.4 feet [30 m]) and nearshore (> 98.4 feet [30 m]) marine habitat in Puget Sound. Section 3(5)(A) of the ESA defines critical habitat as "(i) the specific areas within the geographical area occupied by the species, at the time it is listed

. . . on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and (ii) specific areas outside the geographical area occupied by the species at the time it is listed . . . upon a determination by the Secretary that such areas are essential for the conservation of the species."

Based on the best available scientific information regarding natural history and habitat needs, we developed a list of physical and biological features essential to the conservation of adult and juvenile bocaccio, and relevant to determining whether proposed specific areas are consistent with the above regulations and the ESA section (3)(5)(A) definition of "critical habitat." The physical or biological features essential to the conservation of bocaccio fall into major categories reflecting key life history phases:

- Adult bocaccio: We designated sites deeper than 98 feet (30 m) that possess (or are adjacent to) areas of complex bathymetry. These features are essential to conservation because they support growth, survival, reproduction, and feeding opportunities by providing the structure to avoid predation, seek food, and persist for decades. Several attributes of these sites affect the quality of the area and are useful in considering the conservation value of the feature in determining whether the feature may require special management considerations or protection, and in evaluating the effects of a proposed action in a section 7 consultation if the specific area containing the site is designated as critical habitat. These attributes include: 1) quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities; 2) water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities; and 3) structure and rugosity to support feeding opportunities and predator avoidance.

- Juvenile bocaccio: Juvenile settlement sites located in the nearshore with substrates such as sand, rock, and/or cobble compositions that also support kelp. These features are essential for conservation because they enable forage opportunities and refuge from predators, and enable behavioral and physiological changes needed for juveniles to occupy deeper adult habitats. Several attributes of these sites affect the quality of the area and are useful in considering the conservation value of the feature in determining whether the feature may require special management considerations or protection, and in evaluating the effects of a proposed action in a section 7 consultation if the specific area containing the site is designated as critical habitat. These attributes include: 1) quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities; and 2) water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities.

Regulations for designating critical habitat at 50 CFR 424.12(b) state that the agencies shall consider physical and biological features essential to the conservation of a given species that "may require special management considerations or protection." Joint NMFS and USFWS regulations at 50 CFR 424.02(j) define "special management considerations or protection" to mean "any methods or procedures useful in protecting physical and biological features of the environment for the conservation of listed species." We identified a number of activities that

may affect the physical and biological features essential to bocaccio such that special management considerations or protection may be required. Major categories of such activities include: 1) nearshore development and in-water construction (e.g., beach armoring, pier construction, jetty or harbor construction, pile driving construction, residential and commercial construction); 2) dredging and disposal of dredged material; 3) pollution and runoff; 4) underwater construction and operation of alternative energy hydrokinetic projects (tidal or wave energy projects) and cable laying; 5) kelp harvest; 6) fisheries; 7) nonindigenous species introduction and management; 8) artificial habitat creation; 9) research activities; 10) aquaculture, and 11) activities that lead to global climate change.

Overall, the status of critical habitat in the nearshore is impacted in many areas by the degradation from coastal development and pollution. The status of deepwater critical habitat is impacted by remaining derelict fishing gear, and degraded water quality among other factors. Pollutants affect water quality, sediment quality, and food resources in the nearshore and deepwater areas of critical habitat.

Benthic habitats have benefited from the removal of thousands of shallow water derelict fishing nets, though deepwater derelect nets and continued accumulation of derelict crab and shrimp pots change benthic habitat with uncertain impacts to habitat conditions (NMFS 2016c). Shoreline armoring and stormwater runoff continue to degrade rearing habitats, such as kelp, prey resources, and increase sediment contamination (NMFS 2016c).

2.2.8 Killer Whale Critical Habitat

The final designation of critical habitat for the SR killer whale DPS was published on November 29, 2006 (71 FR 69054). Critical habitat consists of three specific areas: (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. These areas comprise approximately 2,560 square miles of marine habitat. Based on the natural history of the Southern Residents and their habitat needs, NMFS identified the following physical or biological features essential to conservation: (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) Passage conditions to allow for migration, resting, and foraging.

Water Quality. Water quality in Puget Sound, in general, is degraded as described in the Puget Sound Partnership Recommendations and subsequent Action Agenda (Puget Sound Partnership 2014). Toxic chemicals in Puget Sound persist and build up in marine organisms including Southern Residents and their prey resources, despite bans in the 1970s of some harmful substances and cleanup efforts. The primary concern for direct effects on whales from water quality is oil spills, although oil spills can also have long-lasting impacts on other habitat features. The Environmental Protection Agency and U.S. Coast Guard oversee the Oil Pollution Prevention regulations promulgated under the authority of the Federal Water Pollution Control Act. There is a Northwest Area Contingency Plan, developed by the Northwest Area Committee, which serves as the primary guidance document for oil spill response in Washington and Oregon. In 2009, the Washington State Department of Ecology published a new Spill Prevention,

Preparedness, and Response Program Annual Report describing recent accomplishments and declining trends in spill incidents per transit (WDOE 2009).

Prey Quantity, Quality, and Availability. Most wild salmon stocks throughout the Northwest are at fractions of their historic levels. Beginning in the early 1990s, 28 ESUs and DPSs of salmon and steelhead in Washington, Oregon, Idaho, and California were listed as threatened or endangered under the ESA. Historically, overfishing, habitat losses, and hatchery practices were major causes of decline. Poor ocean conditions over the past two decades have reduced populations already weakened by the degradation and loss of freshwater and estuary habitat, fishing, hydropower system management, and hatchery practices. While wild salmon stocks have declined in many areas, hatchery production has been generally strong. Total7 Chinook abundances coastwide increased significantly from the mid-1990s to the early 2000s, but have declined in subsequent years (PFMC and MEW 2008).

Contaminants and pollution also affect the quality of SR killer whale prey in Puget Sound. Contaminants enter marine waters and sediment from numerous sources, but are typically concentrated near areas of high human population and industrialization. Once in the environment these substances proceed up the food chain, accumulating in long-lived top predators like SR killer whales. Chemical contamination of prey is a potential threat to SR killer whale critical habitat, despite the enactment of modern pollution controls in recent decades, which were successful in reducing, but not eliminating, the presence of many contaminants in the environment. The size of Chinook salmon is also an important aspect of prey quality (i.e., Southern Residents primarily consume large Chinook), and any reduction in Chinook salmon size can affect the prey feature and the conservation value of their critical habitat. In addition, vessels and sound may reduce the effective zone of echolocation and reduce availability of fish for the whales in their critical habitat (Holt 2008).

Passage. Southern Residents are highly mobile and use a variety of areas for foraging and other activities, as well as for traveling between these areas. Human activities can interfere with movements of the whales and impact their passage. In particular, vessels or acoustic disturbance may present obstacles to whale passage, causing the whales to swim further and change direction more often, which can increase energy expenditure for whales and impact foraging behavior (review in NMFS 2011).

2.3 Action Area

"Action area" means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). The action area includes the project footprint and all surrounding areas where project activities could potentially affect the environment. The extent of the action area encompasses direct and indirect effects, as well as any effects of interrelated or interdependent actions.

The action area was determined based on the anticipated sound pressure levels generated both above water and in-water during construction (impact and vibratory pile driving). The measures of the farthest-reaching effects are: 1) the distance that underwater sound generated by the action

intersects with a land mass or where it attenuates to background levels, and 2) the areas that the above water sound attenuates to background levels (
Figure 1). The Services assume that sound travels in a straight line and is absorbed by land and does not reflect or bend.

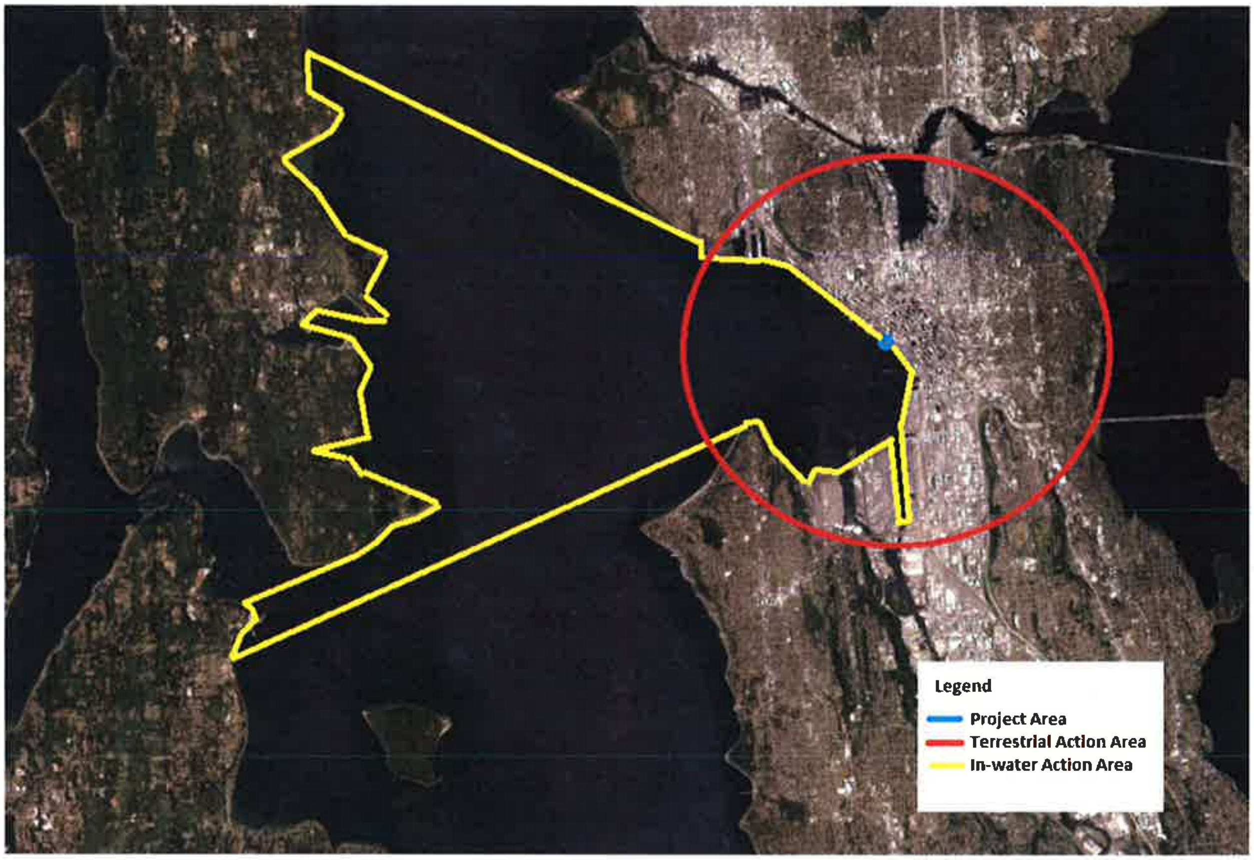

Figure 1. Project area and the action area for the proposed project.

Temporarily elevated sound pressure levels (SPLs) resulting from impact pile installation are expected to have the farthest reaching effects in both the aquatic and terrestrial environment. To estimate the in-water geographic area in which measureable effects to listed species may occur, the distance at which transmission loss (TL) attenuates to sound pressures below specified thresholds are determined. Calculating TL is extremely complicated, and is influenced by site-specific conditions. A practical spreading model, as described by Davidson (2004, p. 2) [TL = 15*Log(R)] is used to estimate the distances at which injury and behavioral disruption to listed species are expected. This model assumes that underwater SPLs decrease at a rate of 4.5 dB per doubling distance.

The in-water action area is defined as the radius within which underwater sound levels generated by pile driving and removal attenuate to background levels (124 dB_{RMS}, City of Seattle 2016). Using the practical spreading loss model, sound from vibratory driving and removal is not expected to be reduced to background levels prior to being absorbed by land at Bainbridge

Island. The extent of the action area is therefore defined as the marine environments of Elliott Bay, Puget Sound from Manchester, just southwest of Bainbridge Island, to Ferncliff on Banbridge Island, and the East Waterway of the Duwamish River.

Similarly, the extent of the above-water geographic area for the action area is based on the furthest extent of in-air sound (denoted as dBA[6])[7]. To estimate the extent of in-air sound we use a spherical spreading loss model which accounts for a 6 dB reduction per doubling of distance for a point noise source in a "hard site" environment (WSDOT 2017). Impact pile driving will result in the greatest noise levels during project construction. Impact pile drivers result in a 110 dBA_{Lmax} in-air noise level at 50 feet. The ambient sound level near the project site, along the Seattle seawall, is 65 dBA_{Leq} (SDOT 2012a). Project related in-air sound is expected to attenuate to ambient sound levels (65 dBA_{Leq}) within approximately 12,800 feet (approximately 2.5 mi) across the water[8]. On land, this estimate is somewhat conservative, because the topography of the surrounding area, especially the downtown Seattle area, has steep hills and tall buildings that will greatly reduce the distance increased sound levels will travel landward of the project site.

2.4 Environmental Baseline

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 (50 CFR 402.02).

The project area is located in Elliott Bay along the Seattle waterfront. The aquatic action area is defined as the marine environments of Elliott Bay and Puget Sound from Manchester, just southwest of Bainbridge Island to Ferncliff on Banbridge Island (see Figure 1). The baseline conditions of the marine environment throughout the action area are very similar. While specific information may be provided for Elliott Bay or the project area along Seattle's seawall, these conditions are similar to those found within Puget Sound between Elliott Bay and Bainbridge Island.

Current conditions within the action area have resulted from over 100 years of development. The action area, and more specifically, Elliott Bay, is extensively developed. Prior to development, Elliott Bay consisted of intertidal mud, sand flats, and wetlands. Extensive filling, dredging, and grading have resulted in Elliott Bay having one of the highest degrees of shoreline modification in Puget Sound at over 80 percent (Kerwin and Nelson 2000). Most shoreline modifications, such as seawalls and bulkheads, were placed to protect urban and residential development

---

6 Throughout this document, the reference value for in-air sound is 20 µPa and in-water sound dB peak pressure is 1 µPa.

7 See definitions under the Exposure to Elevated Underwater Sound Pressure Levels, Sound Metrics and Key Terms section.

8 This distance is conservative as two different sound metrics are used in the calculation. Available data on the in-air sound level of an impact pile driving is denoted in dBA_{Lmax}, while available data on the ambient sound level is denoted in dBA_{Leq}. Using a maximum sound level (Lmax) and estimating the effect of transmission loss to an average or continuous sound level (Leq) will provide a larger action area than if both values were in Lmax. Data for both values denoted the same way is not available.

beginning in the early 1900's. Overwater structures currently occupy over 65 percent of the Elliott Bay shoreline and is highest along the downtown Seattle waterfront (City of Seattle 2003). Since the action area is so highly developed, current activities try to improve the physical, chemical, and biological conditions within the action area, but overall, the action area continues to be negatively impacted by the extensive urban and industrial developments.

2.4.1 Physical Conditions

Depth and Circulation

Elliott Bay has a surface area of approximately 20 km^2 (7.7 mi^2) and a volume of approximately 2,491 hectare meters (20,200 acre-feet) (Baker 1982). The greatest depth of Elliott Bay is 283 meters (930 feet) with an average depth of 62 meters (205 feet). Depths along the seawall range from about -0.76 meters (-2.5 feet) to about -9 meters (-30 feet) MLLW. Depths at the outer edges of the piers are typically around -15 meters (-50 feet). The hydraulic residence time in the inner harbor area of Elliott Bay typically ranges from 1 to 10 days, with variation associated with weather patterns. Several studies have found a counter-clockwise circulation pattern in Elliott Bay, with discharges from the Duwamish Waterway flowing north along the downtown seawall corridor before flowing westward to Puget Sound (Ecology 1995; URS Engineers and Evans-Hamilton 1986; Ebbesmeyer et al. 1998). Current flow velocities are typically low and parallel to the seawall (Silcox et al. 1981). Currents during flood tides are stronger and tend to be in more of a clockwise direction, while during ebb tides currents were weaker and counterclockwise (Winter 1977).

The average tidal range in Elliott Bay is 3.4 meters (11.3 feet) (USACE 2008). The MHHW line is 2.75 meters (9.02 feet) and MLLW is -0.71 meters (-2.34 feet) [NAVD88] (NOAA 2011). The maximum recorded high tide elevation in Elliott Bay is 3.69 meters (12.12 feet) (NAVD88) (NOAA 2011). The elevation of the top of the existing seawall, piers, and the adjacent Alaskan Way road surface is approximately 4.8 meters (16 feet).

Human activities have significantly changed the natural processes and habitats in the action area. Hydrology has been modified as a result of filling in the nearshore zone, dredging, vessel currents and waves/wakes, reduction of flows from the Duwamish River (diversions of the Black and White rivers), and changes in stormwater runoff due to urbanization and rerouting of flows.

Substrate

The primary substrates found within the action area include fine sediment, sand, gravel, cobble, rock/riprap, and large wood. Fine sediments, found in the deeper areas of Elliott Bay where currents are low, include the deposited organic material that tends to settle in marine waters (i.e., dead and decaying plankton). Silts and organic materials are mixed with sands in many parts of the action area (Anchor QEA 2012).

Approximately 70 percent of the substrate along the seawall has been mapped as a sand/silt/shell hash mixture (Anchor QEA 2012;

Figure **2**). Sand is found in the intertidal, nearshore subtidal, and deep water environments. Sandy bottoms are shaped by natural hydrologic characteristics and vessel currents that move sand throughout the environment. Natural input of sediment into the area from feeder bluffs is currently very limited (Anchor Environmental 2004).

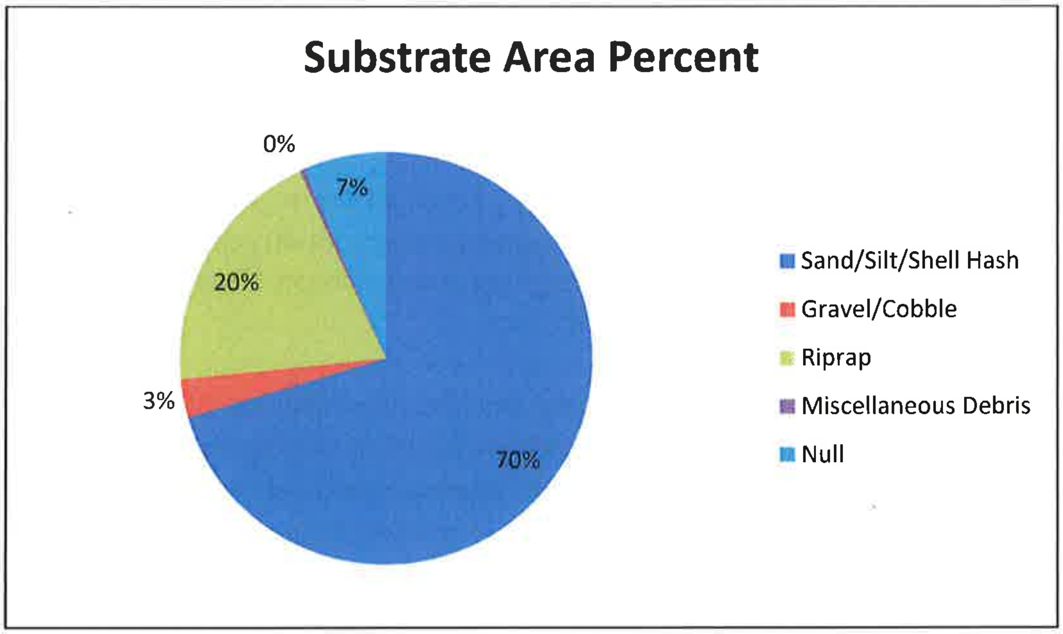

Figure 2. Substrate type mapped along the Seattle seawall (Source: Anchor QEA 2011).

Gravel is the natural substrate of the nearshore in many areas of Puget Sound due to the underlying geology and hydrologic/hydraulic processes. Gravel is limited to a few very small locations and comprises only three percent of the area (

Figure **2**). Due to the proximity of the project to the mouth of the Duwamish River, gravel may not have been a major component of the natural environment, except along the beaches (historic photos confirm beaches with small gravel and sand along the Seattle waterfront). Cobble is similar to gravel in that it is a natural substrate of the nearshore environment. Cobble provides suitable substrate for a variety of macroalgae, invertebrates, and salmonid prey species. Cobble is rare along the seawall.

There are no known natural rock outcrops or deposits along the seawall; the source of rock is from the placement of quarried stone for seawall and bank protection. Rock provides a sturdy substrate for bull kelp and other macroalgae to fasten to, substrate for various invertebrates, and refuge for a variety of invertebrates and fish. Rock is found in multiple locations along the seawall and occupies approximately 20 percent of the project area (Anchor QEA 2011;

Figure 2). Natural large wood essentially does not occur in the action area due to active removal of wood as a navigation hazard, and the lack of recruitment from the nearshore area, since there is little to no riparian vegetation along the Seattle waterfront.

Shoreline Conditions

Most of the shoreline along the eastern portion of the action area is comprised of the Seattle seawall that extends for 2,184 meters (7,166 feet) from Pier 48 in the south to Olympic Sculpture Park in the north (S. Washington to Broad streets). The existing seawall is a vertical structure comprised of concrete, steel sheet pile and treated timber. In addition, there are 12 large overwater pier structures in the area: Colman Dock and Seattle Fire Station No. 5, Pier 54, Pier 55, Pier 56, Pier 57, Waterfront Park, Seattle Aquarium (Piers 59 and 60), Piers 62/63, Pier 66, Pier 67, Pier 69, and Pier 70. Cumulatively, the pier structures account for 60 percent of the linear length of the seawall and represent overwater coverage and shading of 50 to 60 percent of the nearshore area.

The historical construction of the Seattle waterfront and the placement of fill to facilitate development and use of the waterfront for commerce and industry eliminated the natural shoreline. There is currently no natural shoreline along the seawall. There is one small beach north of Pier 48 that is comprised of sand, gravel, bricks, and riprap that is exposed during low tides (

Figure 3). The Seawall Replacement Project is constructing a shallow (low tide) habitat bench along the entire seawall and placing habitat structures at a few locations along the seawall to provide habitat complexity along the nearshore.

Figure 3. Small beach north of Pier 48.

In 2013, the City of Seattle began replacing the seawall. The new seawall is being installed between 10 and 15 feet landward of the existing structure to create a shallow intertidal habitat bench along the whole length of the seawall to improve the migratory corridor. A light penetrating cantilevered sidewalk is being installed over the habitat bench to increase light levels under the piers. In addition, the new seawall will have a textured, cobbled surface with shelves to promote growth of vegetation and marine invertebrates. Construction is occurring in stages and is scheduled to be complete in 2020.

The uplands along the Seattle waterfront are virtually completely impervious surfaces. Extensive urbanization has essentially eliminated most terrestrial and riparian plants. The only vegetation present is street trees and some planter boxes and potted plants on piers.

2.4.2 Water Quality Conditions

Water quality in Elliott Bay has been impaired by decades of various land use activities and discharges. Ecology and King County have ambient marine water quality monitoring stations in Elliott Bay. Both of these agencies have focused their sampling on conventional parameters. Ecology monitors fecal coliform bacteria, chlorophyll, nitrate, ammonium, silicate, turbidity, temperature, salinity, pH, and DO. King County monitors temperature, salinity, water density, DO, nutrients, chlorophyll, and fecal coliform bacteria.

Temperature

Water temperature data in Elliott Bay were collected during surveys for non-indigenous species at seven sites in 2001 and were between 12 °C (53.6 °F) and 16 °C (60.8°F) (WDNR 2001). Ecology conducted monthly surveys of water quality in Elliott Bay between 1991 and 2002. Results from these surveys showed that at 5 meters (16.4 foot) depths, water temperature generally fluctuates between 7.7 °C (45.8 °F) and 16.4 °C (61.5 °F) (Ecology 2006).

Dissolved Oxygen

Dissolved oxygen in Elliott Bay ranges between approximately 5.5 and 10 mg/L in winter and spring, respectively (King County 2009). Elliott Bay is listed as a Category 1 waterbody for DO in most areas and meets standards. However, one monitoring station in central Elliott Bay was listed as a Category 2 waterbody (Category 2 is for waters of concern, but that do not require an improvement plan at this time) for DO in the 2006 list (Ecology 2006). King County data collected in 2002 and 2003 showed four instances of DO levels lower than minimum criteria. However, staff from Ecology's Marine Unit reviewed these data and determined that the sample location is subject to incursions of upwelling with low DO bottom waters. This upwelling shows no evidence of human-caused sources and is therefore likely a natural condition (Ecology 2006).

Chemical Contamination and Nutrients

The project area is located within industrial and commercial areas of Seattle that were first developed between the 1870s and the early 1900s. In general, the waterfront area is underlain by fill that was placed in the early 1900s that covered and incorporated timber and debris previously used in the construction of piers, wharves, and trestles. As a result of the industrial and commercial uses of this area, historical land uses potentially resulted in releases of contaminated materials into the surrounding environment. Some of these legacy pollutants in sediments might be periodically re-suspended in the water column due to wave action, vessels, and currents and if so, episodically degrade water quality.

Elliott Bay receives water runoff from several sources including stormwater discharges and groundwater flows. Other existing sources of potential contaminants to the nearshore water column in Elliott Bay include:

- Combined sewer overflow (CSO) events,
- Vessel discharges,
- Discharges from pier facilities,
- Dumping of trash and other materials from the uplands, and
- Atmospheric deposition.

Primary sources of nutrients (i.e., nitrogen and phosphorus) in Elliott Bay are from upwelling of nutrient-rich water, input from land sources, recycling and re-suspension of nutrients between surface waters and sediments (Harris 1986), decomposition of plants and animals, and waste disposal. Nutrient-rich water from the Pacific Ocean provides a continuous supply of macronutrients to Puget Sound. During times of calm weather or reduced tidal action, reduced nutrient supply can limit photosynthesis in the surface waters in these areas (Williams et al 2001). Increased river discharge, lack of wind, and neap tidal cycles (minimum tidal range

during first and third quarter of the moon phase) enhance stratification and slow vertical mixing of nutrients to the surface (Rensel Associates and PTI Environmental Services 1991).

Heavy metals (arsenic, cadmium, copper, lead, mercury, silver, and zinc), phthalates, and polycyclic aromatic hydrocarbons (Polycyclic Aromatic Hydrocarbons [PAHs], found in the creosote pilings) are detected in most water quality samples in Elliott Bay. Ambient dissolved copper and dissolved zinc concentrations for Elliott Bay are approximately 0.7 and 4.1 micrograms per liter (µg/L), respectively (Curl et al. 1988). A number of studies have observed bioaccumulation of PAHs, PCBs, and mercury in marine animals of Puget Sound and Elliott Bay, including mussels, squid, fish larvae, Chinook salmon, coho salmon, osprey, gray whales, killer whales, and harbor seals (NMFS 1993; KCEL 1998; Ross et al. 1998; USEPA and PSWQAT 1999; Cullon et al. 2001; Lambourn et al. 2001; PSP 2007).

Stormwater

Along the seawall, there are seven major storm drain outfalls managed by the City, three separated storm drain outfalls, two CSOs, and two shared (CSO/stormwater) outfalls. The separated stormwater outfalls managed by the City are at the ends of S. Washington Street, Seneca Street, and Pine Street. There are two CSO outfalls at the end of Washington and Vine streets. In addition, there are currently approximately 50 small, individual outfalls that convey runoff directly to Elliott Bay (USACE 2008). These outfalls typically convey runoff from small areas of the roadway within the project area. Where the separated storm drain system and the combined sewer system share outfalls along the seawall, at University Street and Madison Street, the separated storm drain connections to the outfall pipes occur downstream of the CSO diversion structure, and thus the separated storm drainage does not affect the occurrence or magnitude of the CSO discharge at those outfalls. Under the Seawall Replacement Project, many of the smaller outfalls will be removed and combined to discharge to the larger outfalls, and some of the stormwater will be treated prior to discharge into Elliott Bay.

The water quality condition is influenced by many contributing factors from both within and outside the action area. The Seattle Waterfront is comprised almost entirely of impervious surfaces. The stormwater collection and conveyance network along the downtown waterfront was generally constructed in the 1930s and then upgraded in the 1980s as part of improvements to the Alaskan Way road surface, sidewalk, and seawall. Almost the entire existing Alaskan Way road surface within the project limits is classified as pollution generating impervious surface (PGIS) according to the City's stormwater code (SMC 22.801.170). Runoff from the project area, including the road surface, sidewalks, parking lots, driveways, trolley tracks, landscaping, and trail, drains to the separated stormwater system, and then to Elliott Bay. A small portion, approximately 1.4 acres east of the Alaskan Way roadway in the vicinity of Pike and Pine streets, drains to the City's combined sewer system. A very small portion infiltrates to the groundwater.

Outside, but flowing through the action area, stormwater and wastewater from Seattle and north King County, flow to and are treated at the West Point Wastewater Treatment Plant in Seattle. Twenty-nine percent of the City drains to the combined sewer system. With measurable rain occurring at least 100 days per year in the Seattle area, stormwater discharges are common along

the waterfront during most months. Combined sewer overflows occur in varying frequencies when the capacity of that portion of the combined system is exceeded by stormwater inflows.

Four CSO outfalls are located along the seawall and discharge into Elliott Bay (Vine, University, Madison, Washington). Individual CSO outfalls in the project footprint have discharged from zero to 26 times in a year based on recent data from 2008-2012 (City of Seattle 2013). The average annual number of CSO discharges based on these years was 1.8 for Vine, 0.2 for University, 5.2 for Madison, and 0 for Washington. Overflows are most likely to occur from October to March coinciding with the greatest frequency and depth of precipitation, but may occur at other times of the year during heavy rain. In the years of 2008-2012, the duration of CSO overflow events ranged from a zero to 54.68 hours (City of Seattle 2013).

The key pollutants of concern in roadway runoff are total suspended solids, total copper, dissolved copper, total zinc, and dissolved zinc. The expected loading from impervious surface runoff (Alaskan Way) is shown in Table 2 (SDOT 2012b).

Table 2. Existing Stormwater Pollutant Loading from Alaskan Way.

	Existing Conditions		
	Loads (pounds per year)		
	Lower Quartile	**Median**	**Upper Quartile**
Total Suspended Solids	4,051	5,239	7,023
Total Copper	0.97	1.19	1.81
Dissolved Copper	0.25	0.30	0.47
Total Zinc	5.32	6.97	9.22
Dissolved Zinc	1.44	1.80	2.92

Groundwater Quality

Groundwater area can be found from 7 to 15 feet (2.1 to 4.5 meters) below the ground surface (SDOT 2012b). Groundwater levels within the action area vary with Elliott Bay tidal fluctuations (SDOT 2012b). The groundwater is conveyed in discontinuous fill and native glacially overridden materials that have highly variable hydraulic conductivities. The water table (shallow groundwater surface) is flat for the most part, but is connected hydrologically to Elliott Bay tides (FHWA 2010). Near the intersection of Alaskan Way with Yesler Wa, data collected in observation wells indicated that for an 11-foot (3.35 meters) tidal range, groundwater levels fluctuated by 8 feet (2.4 meters). However, in other areas along the Seattle waterfront, groundwater level fluctuations were much less, typically in the 3-foot (0.9 meters) range (SDOT 2012b).

Groundwater flows are dependent on subsurface soils, with coarse-grained sand and gravel layers having higher groundwater discharge rates than occurs in fine-grained soils. Groundwater flow occurs horizontally and towards Elliott Bay (SDOT 2012b). Small groundwater seeps have been observed coming through the seawall but these will be eliminated with the new seawall.

Soil and groundwater contaminant levels that are less than the Model Toxics Control Act (MTCA) clean-up levels (CULs) for unrestricted land use are referred to as "below levels of concern." Contaminant levels above the MTCA CULs for unrestricted land use are referred to as "above levels of concern" (SDOT 2012b). Low to moderate levels (below levels of concern) of soil and groundwater contamination occur throughout the urban Seattle waterfront and within the project footprint. Concentrations of contaminants in soils do occur above residential or general use CULs in some areas based on the history of industrial activity along the waterfront. Sources of contamination are not well defined.

Metals and PAH contamination in groundwater occur at low to non-detected levels between S. Washington and Virginia streets. Near Colman Dock, metals that exceeded the MTCA CULs (i.e., they are above levels of concern) include arsenic, cadmium, copper, lead, mercury, and silver. Petroleum hydrocarbons are generally present below levels of concern within the action area with the exception of the historic piers where concentrations were found to exceed the MTCA CULs. These exceedances are likely attributed to historical contamination in the area of the Seattle Steam Company. The Seattle Steam Company site (south of Union Street and north of University Street) is an active MTCA cleanup site. At that site, groundwater is contaminated with Bunker C oil (i.e., Number 6 fuel oil).

Between Virginia and Broad streets, metals (with the exception of one area) and PAH contamination in groundwater did not exceed the MTCA CULs (i.e., they were below levels of concern). Petroleum hydrocarbons were not detected in the groundwater throughout this area. However, metals detected north of Pier 66 at concentrations that exceeded MTCA CULs include arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc.

In-Water Sediment Quality

The most prevalent chemicals of concern (COCs) for in-water sediment areas from historic land uses include petroleum products, metals, and PAHs. Priority COCs include the following:

- Total Petroleum Hydrocarbons (in the gasoline and diesel range): These contaminants include gasoline, diesel, bunker fuel, and lube oils. Historical uses were widespread and associated with a variety of land uses. Lube oils were used extensively by the railroads. Diesel was used to heat businesses and homes.

- Metals: Heavy metals, including arsenic, cadmium, copper, lead, mercury, silver, and zinc, are associated with shipyards and boat maintenance facilities, metal works, foundries, and plating operations.

- Polycyclic Aromatic Hydrocarbons: PAHs are petroleum hydrocarbons that are produced as byproducts of fuel burning and are often formed by incomplete combustion of carbon-containing fuels. They are also present in creosote that was used to treat timber and/or wood pilings and used historically along the seawall to support the existing structure and relieving platform. PAHs may also be associated with petroleum releases such as leaking heating oil underground storage tanks, lubricating oils used by railroads, and burned timbers. In general, PAHs are relatively insoluble in water and bind to soil particles.

- Polychlorinated Biphenyls: The most common sources of PCBs are spills or leaks of dielectric fluids from PCB-containing equipment such as transformers or switches, which are often found at power stations. PCBs have also been used in many other products, such as capacitors, heat transfer systems, inks and carbonless copy paper, the ballasts of some fluorescent light fixtures, paints, caulking, and sealant materials (Windward Environmental 2010). In general, PCBs tend to adhere to organic matter in soil and are insoluble in water.

The most widespread contaminants in sediments are metals, and in particular, mercury. All known analyses performed in this nearshore sediment area resulted in detections, as well as several exceedances of the Sediment Quality Standards chemical screening criterion for mercury (SDOT 2012c). PAHs are also commonly reported in sediments in the nearshore south of the Olympic Sculpture Park. Generally, moderate levels (below the Sediment Management Standards/Cleanup Screening Level criteria) of mercury and PAH contamination have been identified in the sediments from Seneca Street (Pier 55) and south. In this area, the most common contaminants in order of reported occurrence are mercury, PAHs, PCBs, and other metals including copper, silver, and zinc. North of Pier 55, the primary contaminants are also metals (mercury, copper, lead, zinc, silver), PAHs, and isolated areas with exceedances of PCBs. Metals are the primary COC north of Pier 62/63, while PAHs and PCBs are generally less than levels of concern (less than the Sediment Management Standards/Cleanup Screening Level criteria) in this area.

Historical filling, disposal of ship bunker materials, and wastewater discharges have likely contributed to the observed sediment contamination conditions. In general, the surface sediment concentrations continue to improve over time, consistent with the implementation of source controls (primarily in the 1970s) and ongoing natural recovery (e.g., sedimentation) processes in the area. Cleanup actions (e.g., placement of sediment caps at Colman Dock, Pier 53-55, and Pier 64/65 [Romberg 2005]) have been conducted in some areas over the past 22 years.

The contaminants present in the in-water sediments have the potential to bioaccumulate through the food chain, and may currently be posing some risk to listed species. However, the most contaminated areas have been already been capped, and the remaining contaminants are below cleanup threshold levels.

2.4.3 Biological Conditions

Macroalgae

As a result of the significant number of structures and shading associated with the numerous overwater structures, primary productivity is significantly reduced from natural conditions. Macroalgae communities between and under piers were mapped and photographed to quantify their distribution (Anchor QEA 2011;
Figure **4**,
Figure **5**, and

Figure 6). Approximately 50 percent of the area in front of the seawall had no macroalgae growth, presumably due to shading. Between piers, a moderately diverse macroalgae and associated invertebrate community occurs. Based on visual observations, the extent of existing kelp beds were mapped with the total area calculated to approximately 1.75 acres (0.7 ha) (Anchor QEA 2011). Bull kelp (*Nereocystis lutkeana*) is present along the seawall in discrete small patches between piers. The distribution appears to be associated with the presence of rocky substrate for attachment, water depths between 7 and 15 feet (2 to 4.5 meters), and areas protected from boat-caused wave action (USACE 2008).

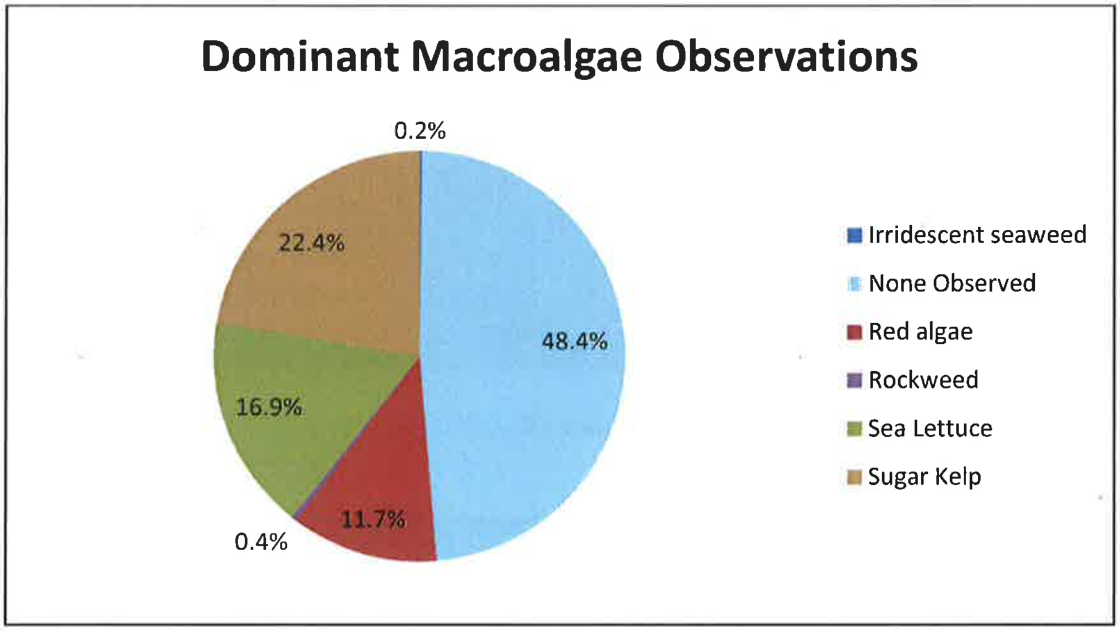

Figure 4. Macroalgae Species Observed in the Project Footprint (Anchor QEA 2011).

Figure 5. Typical Condition under Piers (Anchor QEA 2011).

Figure 6. Macroalgae Community between Piers (Anchor QEA 2011).

In spite of the effects of the overwater structures, native species dominate the aquatic nearshore plant assemblage. Marine algae, including blue-green algae, green algae, diatoms, brown algae, and red algae are found throughout the nearshore in areas where light reaches the substrate. Vascular flowering plants are also found in the nearshore, although the shallow flats they require are now mostly along the seawall. Artificial structures such as floating docks and wood pilings are dominated by sea lettuce (*Ulva lactuca*) and rockweed (*Fucus gardneri*) in addition to various rhodophyta species (USACE 2008; Anchor QEA 2011). Sugar wrack (*Saccharina latissima*) is also associated with these structures, as is *Codium fragile*, *Polyneura latissima*, and *Membranoptera platyphylla* (USACE 2008; Anchor QEA 2011). Large rocky substrate provides a source of attachment for algae such as *Fucus spiralis*, *Endocladia muricata*, *Gigartina papillata*, feather boa kelp (*Egregia menziesii*), *Corallina* sp. and winged kelp (*Alaria* sp.), which are associated with cobble, riprap and concrete (USACE 2008). Overall, primary productivity is moderate along the seawall, but reduced due to shading and lack of normal intertidal depths. Small groundwater seeps have been observed coming through the seawall, but there does not appear to be any change in macroalgae community type or diversity associated with these flows (SDOT 2012d).

Resident and Forage Fish

Most resident fish reside in close proximity to the benthic substrate (rock, gravel, sand, or kelp) throughout the nearshore subtidal zones where they forage on primary consumers or on small invertebrates and fish. Resident fish provide forage for larger fish and marine mammals. Cover, such as kelp and other macroalgae, and interstitial spaces between rocks are important for early life stages of rockfish.

The most commonly observed species within the action area include shiner perch (*Cymatogaster aggregata*), pile perch (*Rhacochilus vacca*), striped sea perch (*Embiotoca lateralis*), tube-snout (*Aulorhynchus flavidus*), kelp perch (*Brachyistius frenatus*), brown rockfish (*Sebastes auriculatus*) and spotted ratfish (*Hydrolagus colliei*) (SDOT 2012e; Anchor QEA 2011). Species common to the demersal zone include Dover sole (*Microstomus pacificus*), English sole (*Parophrys vetulus*), kelp greenling (*Hexagrammos decagrammus*), blackbelly eelpout (*Lycodopsis pacifica*), bay pipefish (*Syngnathus leptorhynchus*), quillback rockfish (*S, maliger*), copper rockfish (*S. caurinus*) and Pacific staghorn sculpin (*Leptocottus armatus*) (SDOT 2012e; Anchor QEA 2011). Species common to the benthopelagic zone (area ranging from the benthos to below surface waters) include spiny dogfish (*Squalus acanthias*), walleye pollock (*Theragra chalcogramma*), snake prickleback (*Lumpenus sagitta*), Pacific sand lance (*Ammodytes hexapterus*), lingcod (*Ophiodon elongatus*), yellowtail rockfish (*S. flavidus*), black rockfish (*S. inermis*), Pacific hake (*Merluccius productus*) and surf smelt(*Hypomesus pretiosus*) (Matsuda et al. 1968; DeLacey et al. 1972; Weitkamp et al. 2000; Anchor Environmental 2003; WSDOT 2006; Toft et al. 2010; SDOT 2012b; Anchor QEA 2011; WDFW 2011b).

Forage fish such as Pacific herring, Pacific sandlance and surf smelt are present in Elliott Bay and the action area, but spawning locations are few. Pacific herring spawning occurs from the Olympic Sculpture Park to Port of Seattle's Terminal 86. Surf smelt and sand lance spawn on the west side of the action area along Bainbridge Island in Eagle Harbor and on Yeomalt Point (WDFW 2011c). Anchor QEA (2011) observed large numbers of surf smelt and sandlance along

the seawall during surveys in July 2011. This is consistent with observations by University of Washington researchers that juvenile forage fish are present in large numbers during summer months along the seawall (SDOT 2012e).

Anadromous Salmonids

At least nine species of native anadromous salmonids are known to occur in the action area and potentially frequent the nearshore and offshore waters as juveniles and adults. Of those, three are federally listed species and include: Chinook salmon, steelhead trout, and bull trout (Matsuda et al. 1968; DeLacey et al. 1972; Groot and Margolis 1991; Weitkamp et al. 2000; Anchor Environmental 2003; Toft et al. 2004; WSDOT 2004; Brennan et al. 2004; Toft and Cordell 2006; Fresh 2006; WSDOT 2006; Toft et al. 2010; SDOT 2012e; Anchor QEA 2011). The close proximity of the action area to the Duwamish Estuary and other stream systems (Weitkamp et al. 2000; WSDOT 2004) causes the nearshore and offshore waters to be a necessary migration corridor for species that spawn in the Green/Duwamish system and could serve as a foraging area.

Pre-spawning adults (primarily Chinook, coho, chum, and pink salmon) returning from the ocean migrate through Elliott Bay and along the Seattle waterfront (WSDOT 2004). Juveniles may move from spawning and rearing areas in the Green River into the Duwamish Estuary and out through the project footprint during outmigration. Some juvenile salmonids migrate west from the Duwamish (along Alki) and some move north along the Seattle waterfront; the limited data available indicates that about half the fish go west and half the fish go north (SDOT 2012e).

Along the seawall, juvenile salmonids are generally more abundant in the shallow waters of the nearshore. Chinook, coho, chum, and pink salmon have been observed in close proximity to the seawall and on the shallow shorelines or beaches within Elliott Bay (Anchor QEA 2012; Toft et al. 2012a, 2012b, 2012c, 2012d, 2013a, 2013b). Adults occur farther offshore and are typically found nearer the surface, upwards from the middle of the water column (Toft and Cordell 2006). Salmonids observed in the project footprint (including Chinook, coho, chum, and pink salmon) have been shown to usually avoid waters underneath overwater structures (Toft et al. 2004; Anchor QEA 2012). Juveniles do school near pier edges at the shade line, as well as in open, non-shaded water, and under particularly low-light conditions, show little preference between non-shaded and shaded areas (WSDOT 2006; Anchor QEA 2012).

Adult and juvenile salmonids (most data are available for Chinook salmon) from other basins such as Lake Washington/Cedar River, Puyallup River, and Snohomish River, also use Elliott Bay and the action area (Brennan et al. 2004). Nelson et al. (2004) captured coded-wire tagged Chinook salmon juveniles in Elliott Bay from multiple watersheds including the Green/Duwamish, Lake Washington, Skykomish, Stillaguamish, Puyallup, and western Puget Sound locations. Nearly 70 percent of Chinook salmon subyearlings captured were from the Green/Duwamish, and roughly 20 percent from the Skykomish system, which has one of the largest Chinook salmon populations in Puget Sound.

Prey species for salmonids are diverse in nearshore marine waters. In Elliott Bay, zooplankton is composed mostly of copepods, but amphipods, mysids, various species of fish larvae, and

euphausiids are all also in abundance (Strickland 1983;Toft and Cordell 2006). Demographics of zooplankton in Elliott Bay are not well understood; however, they are known to provide an important prey base for many species including anadromous fish.

Terrestrial insects are an important prey component for many insectivores in the nearshore, including salmonids (Wipfli 1997; Sobocinski et al. 2010; Duffy et al. 2010). Although little is known about the assemblage of insects in the action area, species known to be present include spiders, dipteran flies, springtails, bark lice, aphids, ants and mites (Toft et al. 2004; Toft et al. 2007; Sobocinski et al. 2010). It has been shown that densities of terrestrial insects in the nearshore are at their lowest where overhanging terrestrial vegetation has been replaced by constructed structures (Toft et al. 2004; Higgins et al. 2005; Sobocinski et al. 2010). Because minimal riparian vegetation is present within the action area, it is assumed that densities of terrestrial insects are quite low.

As a result of shoreline modifications, differences in fish behavior and usage are attributed to changes in water depth, slope, substrate, and shoreline vegetation (Toft et al. 2007). Reduced diversity or density of epibenthic meiofauna reduces prey resources for juvenile salmon. The cumulative impact of numerous and contiguous urban marine structures may be detrimental to the long-term success of numerous species, particularly recovery efforts for anadromous fish species that migrate along shorelines. Migrating juvenile salmon use Puget Sound during out-migration and rearing (Simenstad et al. 1982). Research summarized in Fresh (2006) indicates juvenile Chinook salmon and chum salmon prefer shallow beaches and mudflats in Puget Sound and are the most dependent salmon species on estuarine and nearshore habitats. Shoreline enhancements (e.g., pocket beach, habitat bench, upland vegetation planting, addition of coarse-grained sediments and driftwood) at the Olympic Sculpture Park replaced an armored seawall and riprap shoreline. Results from 3 years of monitoring post-construction indicate a relatively stable beach with rapid development of aquatic and terrestrial biota (Toft et al. 2010). Abundance, diversity, and assemblages of invertebrates and fish have increased compared to baseline conditions (Toft et al. 2010).

Migratory Corridor

The shoreline within the action area is an important migratory corridor for juvenile salmonids emerging from the Green-Duwamish watershed as they journey into Puget Sound and farther into marine waters. The shoreline of Elliott Bay is also used by juvenile salmonids from other watersheds although migratory patterns are not well understood. Fish surveys conducted by Anchor QEA indicate that significant numbers of juvenile salmonids migrate along the seawall from March through August, including chum, Chinook, and coho salmon (Anchor QEA 2012). The existing migratory corridor is highly degraded and is essentially the vertical seawall adjacent to deep water (typically greater than 10 feet [3 meters] deep), with 12 overwater pier structures casting a dark shadow. The Seawall Replacement Project is constructing a habitat bench along the seawall to improve salmonid migration through the area. The Seawall Replacement Project is expected to be completed in 2020.

Key observations from the Anchor QEA (2012) fish surveys are: (1) peak chum salmon counts occurred in April and May; (2) Chinook and coho salmon peak counts occurred in May and June;

(3) juvenile salmon were most often observed at the 3-meter transect (3 meters off the wall) than farther out; (4) juvenile Chinook salmon were more often observed near the seawall than along the piers; and (5) juvenile salmonids avoided going under piers or into the sharp shadow line cast by the pier (were never observed swimming under piers), rather they were observed out at the ends of the piers in deep water to migrate around piers.

In spite of the limitations of the project footprint for use as a migratory corridor, juvenile salmon are present and do use the area, as indicated by surveys by Toft et al. (2010) near the Olympic Sculpture Park.

Non-native Species

Invasive species are alien species whose introduction does, or is likely to, cause economic or environmental harm, or harm to human health (Executive Order 13112). Probable pathways for introduction range from escaped aquaculture to intentional stocking or planting. In marine areas, ballast releases from ships arriving from foreign ports of call are one of the most common mechanisms of spread.

Non-native plants and macroalgae known to occur in the greater Puget Sound area include cordgrass (*Spartina* spp.), Japanese eelgrass (*Zostera japonica*), and Sargassum (*Sargassum muticum*) (MISM 2009). Marine macroalgae considered high risk for invasion to the Puget Sound area include Japanese kelp (*Undaria pinnatifida*) and Caulerpa (*Caulerpa taxifolia*) (WISC 2008, MISM 2009). None of these invasive plants or macroalgae are known to be currently present along the seawall, but may be present elsewhere in Elliott Bay. Various non-native invertebrates have been reported in Puget Sound but are not known to be present along the seawall, including tunicates (*Botrylloides violaceus, Ciona savignyi, Disemnum vexillum*, and *Styela clava*), slender tube amphipod (*Monocorophium acherusicum*), and Asian cumacean (*Nippoleucon hinumensis*) (USGS 2011).

Included on the Washington Invasive Species Council's Watch List are mitten crab (*Eriocheir sinensis*), Atlantic gem clam (*Gemma gemma*), and Leidy's comb jelly (*Mnemiopsis leidy*), all which could be transported by ballast water (WISC 2008). Tunicates are particularly associated with hull fouling communities, thus probably more likely to be introduced via barges or other ship fouling rather than ballast (SDOT 2012e). The action area is at risk for invasion by species that use rocky shorelines or pilings, such as Japanese kelp, mitten crab, Atlantic gem clam, and Leidy's comb jelly.

Noise

The ambient in-air sound level within the action area ranges from 65 dBA_{Leq} in the north to 75 dBA_{Leq} in the middle area (SDOT 2012a). Existing traffic on the Alaskan Way Viaduct is a predominant source of noise in the project vicinity. Existing sources of noise is mainly road traffic, with some local industry and high-altitude aircraft over-flights. The areas surrounding these locations can be categorized as urban. Natural noises such as leaves rustling, light surf, and bird vocalizations are limited.

A range of ambient in-water noise levels have been reported for Elliott Bay. Near the Colman Dock ferry terminal, average in-water noise levels were measured at 123 dBA_{RMS} (Laughlin 2011) and ambient noise levels in Elliott Bay near Pier 70 are reported as 147 dBA_{peak} (re: 1 $\mu Pa^2 \cdot sec$)) (Laughlin 2006). Laughlin (2015) measured underwater background sound levels for three 24-hour periods 2,864 feet northwest of Colman Dock in Elliott Bay. Background sound levels for the three 24-hour periods were 128 dB_{RMS} and 141 dB_{RMS} for just daytime sound, which is heavily influenced by ferry traffic. The City of Seattle monitored background levels for the Seawall Replacement Project (City of Seattle 2016). Background levels averaged 124 dB_{RMS} to 130 dB_{RMS}. For the purpose of this opinion, ambient conditions within the action area are assumed to be 124 dB_{RMS} as reported by the City of Seattle (2016). Noise levels may attenuate towards the north end of the project footprint where fewer vessels are present, but the entire area has high ambient noise levels due to ferry vessel, cruise ship, container ship, and other boat traffic.

The number of vessels (container, grain, and other deep draft vessels) that called to Seattle terminals in Elliott Bay between January 1, 2014 and November 27, 2016 is 2,850 (N. Cladwell, MEPS, pers. comm. 2016). The number of cruise ships was 179 in 2014, 192 in 2015, and 203 in 2016 (Port of Seattle 2016). Approximatley 40,000 ferries and water taxis use Elliott Bay per year (King County 2016, WSDOT 2016a). An unknown number of barge and recreational boats also contribute to the noise levels in Elliott Bay.

2.4.4 Status of the Listed Species and their Critical Habitat in the Action Area

For each listed species below, the presence, densities, and specific life history information within the action area are provided. The habitat and conditions that affect the species are provided within the critical habitat sections.

Chinook Salmon

Chinook salmon in the action area originate from multiple watersheds including the Green/Duwamish, Lake Washington, Skykomish, Stillaguamish, Puyallup, and western Puget Sound locations (Table 3, Nelson et al., 2004). Nearly 60 percent of Chinook salmon juveniles captured were from the Green/Duwamish River, and roughly 20 to 30 percent from the Skykomish River system, which has one of the largest Chinook salmon populations in Puget Sound.

Table 3. Origin of coded wire tags of Chinook salmon captured in Elliott Bay in 2002 and 2003 and the time from release to capture (Nelson et al., 2004).

Hatchery	Area	Distance (mi)	Number		Time from release to capture (d)
			2002	2003	
Soos Cr.	Green/Duwamish	0	83	60	12.4
Grovers Cr.	Suquamish	16	3	2	37.3
Hupp Springs	South Sound		1		50.0
Puyallup Tribe	Puyallup	30	3		75.0
White River	Puyallup	30		1	*
Tulalip Tribe	Snohomish	36	1		27.0
Wallace River	Skykomish	36	42	18	31.6
Gorst Cr.	Sinclair Inlet	19		3	24.3
Issaquah Cr.	Lake Sammamish	9		3	35.3
Univ. of Washington	Lake Washington	9		2	
White Horse	NF Stillaguamish	52		1	*

* Data unavailable as fish were released over broad timeframe.

The study sites in Elliott Bay for Nelson et al. (2004) included Pier 90/91 (north Elliott Bay), Seacrest (south Elliott Bay), Alki (west side of Duwamish Head), RM 0 (East and West Waterways of the Duwamish River), and RM 1 (near Kellogg Island in the Duwamish River). At the Seacrest site, juvenile Chinook salmon, both natural and hatchery, were captured starting in March and continued through August. The highest abundance (mean catch per beach seine set) was in mid-May and mid-June (approximately five Chinook salmon) for natural juveniles, and the end of May to mid-June for hatchery juveniles (approximately 18 Chinook salmon). A few juvenile Chinook salmon, both natural and hatchery, were captured in late January. At Pier 90/91, located along the north shore of Elliott Bay, natural and hatchery juvenile Chinook salmon were captured from mid-April through the last sample at the end of September. Mean catch per seine set was highest at the beginning of July for both natural (approximately 10 Chinook salmon) and hatchery (approximately 14 Chinook salmon).

Immature (blackmouths) and adult Chinook salmon can be found in Elliott Bay from August through March (Nelson 2013, Nelson et al 2004). Adults from the Green-Duwamish River will migrate through Elliott Bay into the Duwamish River from mid-August through the end of November (Nelson et al. 2004). Blackmouths can be in Elliott Bay from November through March depending on availability of bait fish. The Tenfu Derby, the oldest derby fishing for blackmouths in Washington, is held in November and only hatchery fish may be kept. Good fishing locations for blackmouth include the shorelines out to the 150 foot line from the west side of the Duwamish Head, all the way past Harbor Island to Colman Dock (Nelson 2013). The area just south of Colman Dock is a holding area for adult Chinook salmon prior to their migration into the Duwamish River.

Chinook salmon are caught within Marine Area 10 (Puget Sound from Edmonds south to Vashon Island) from June through January (Kraig 2012, 2013). The fewest Chinook are caught in June and the most are caught in July and August (Table 4).

Table 4. 2008-2010 Chinook sport catch in Area 10 – Seattle/ Bremerton.

Month	2008	2009	2010
June	11	15	
July	1407	1367	
August	1241	1783	
September	49	47	
October	320	123	
November	383	83	
December	101	119	
January		150	107

Tribal fishing within Elliott Bay is set by negotiations between WDFW and the northwest treaty tribes during the North of Falcon and Pacific Fisheries Management Council. In general, tribal fishing for Chinook salmon within Elliott Bay occurs in July and August (WDFW and NWIFC 2010). Tribal coho fishing occurs in Area 10 during September and October (WDFW and NWIFC 2010) and incidental Chinook salmon are caught during this time (Zischke, pers. comm. 2013).

Chinook salmon juveniles emigrate from the Green-Duwamish River natal areas to estuarine and nearshore habitats from January through March as fry, and from May through June as larger fingerlings or yearlings (Nelson et al. 2004). Sampling conducted as part of the Seawall Replacemetn Project found Chinook salmon along the shoreline beginning in April and continuing through October (
Figure 7, Toft in litt. 2013a). Peak migration occurred in June. One age 1+ hatchery Chinook salmon was caught at the Olympic Sculpture Park in January. One wild Chinook salmon was captured in early March indicating the start of the emigration period.

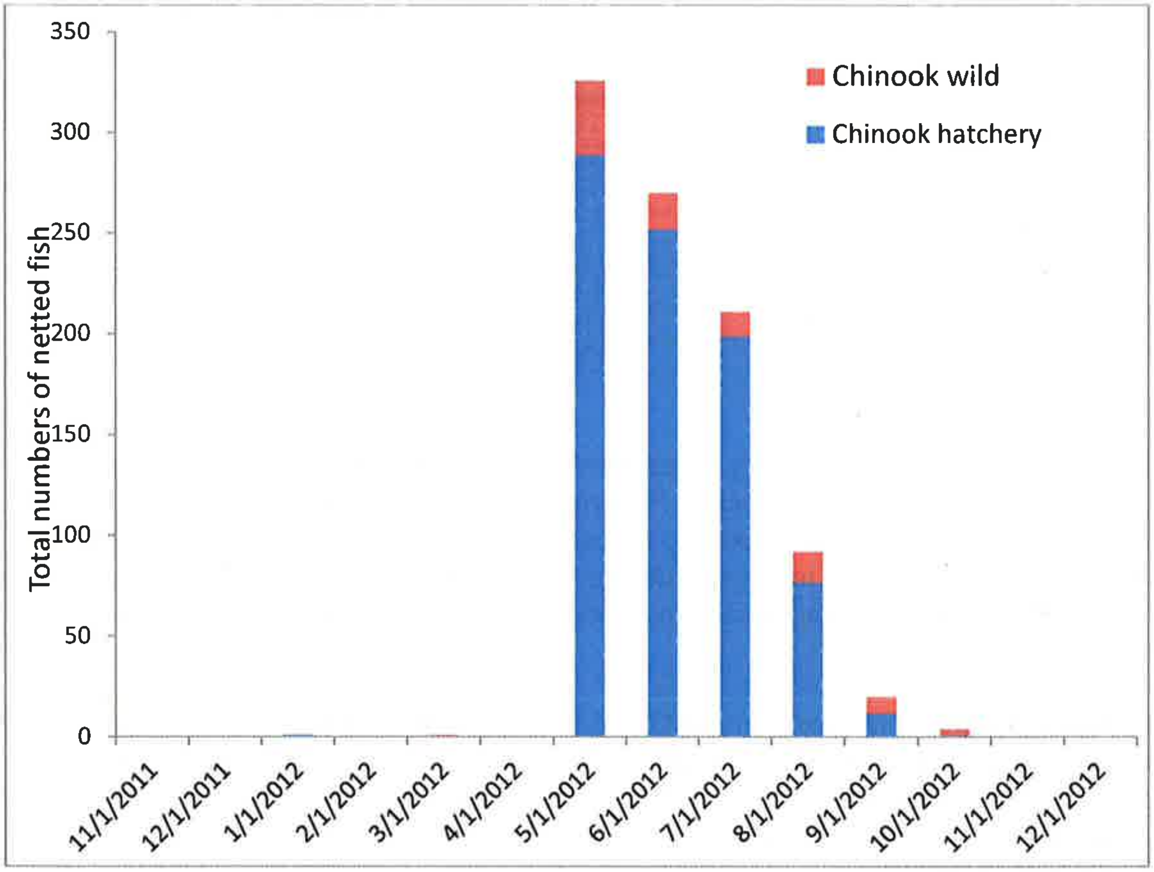

Figure 7. Summary of all wild and hatchery Chinook salmon caught at the six Elliott Bay (three seawall, three beach) sampling sites (Toft in litt. 2013a).

The total number of Chinook salmon found at the three seawall sites in 2012 are shown in Figure 8. Sampling was only conducted once a month. Because Chinook salmon were not captured on April 1, 2012, but were caught on May 1, 2012, juveniles begin migrating along the seawall in April. During spring 2013 sampling, one juvenile wild Chinook salmon was caught on April 3, 2013. Table 5 shows the mean density of Chinook salmon caught along the seawall.

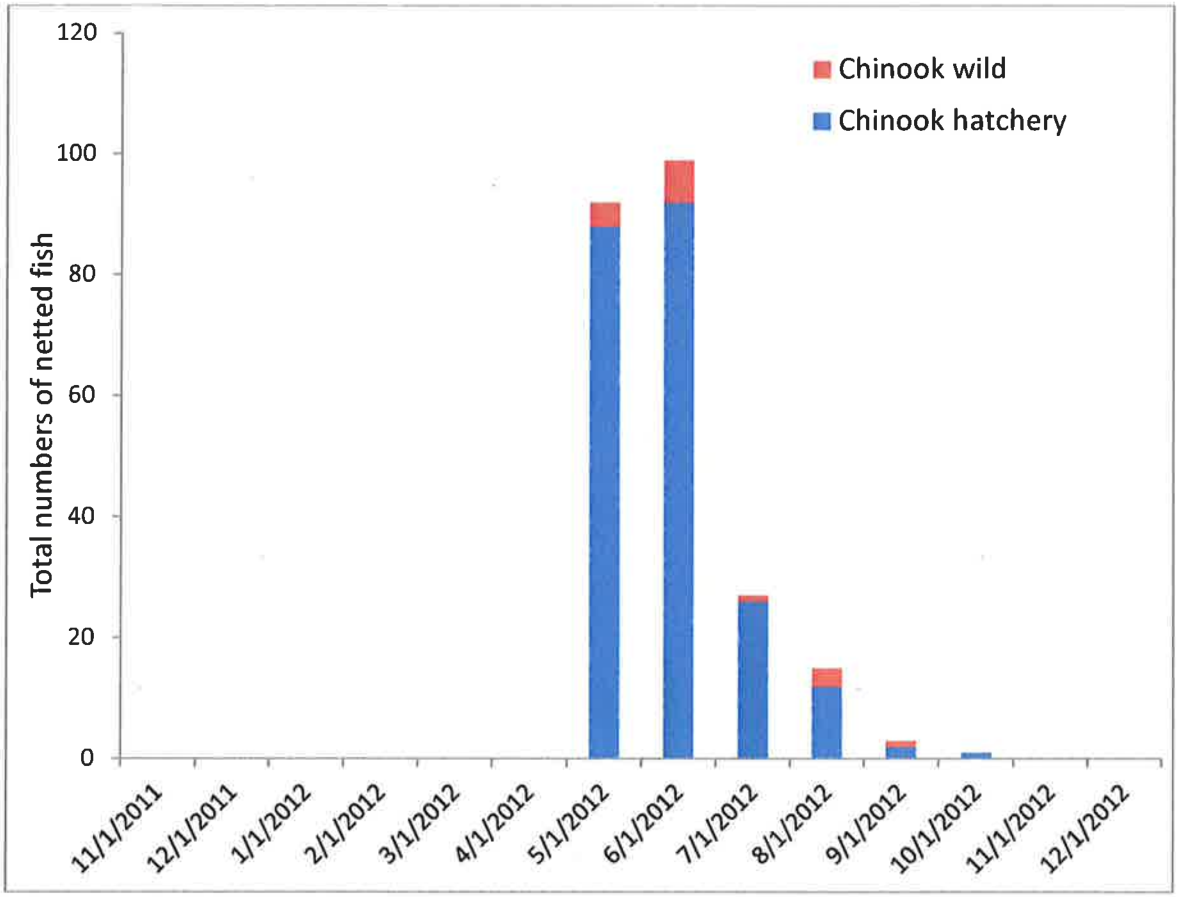

Figure 8. Summary of all wild and hatchery Chinook salmon caught at the three seawall sampling sites in Elliott Bay (Toft in litt. 2013a).

Table 5. Chinook salmon densities (#/520 m^2 [5,597 ft^2]) at three sites along the Seattle Seawall (UW unpublished data).

Month	Aquarium	Colman	Vine St.	Total	Average Seawall Sites
November 2011	0.0	0.0	0.0	0.0	0.0
December 2011	0.0	0.0	0.0	0.0	0.0
January 2012	0.0	0.0	00	0.0	0.0
February 2012	0.0	0.0	0.0	0.0	0.0
March 2012	0.0	0.0	0.0	0.0	0.0
April 2012	0.0	0.0	0.0	0.0	0.0
May 2012	7.0	0.0	10.5	17.6	5.9
June 2012	35.1	8.8	50.9	94.9	31.6
July 2012	3.5	1.8	14.1	9.3	6.4
August 2012	7.0	5.3	7.0	19.3	6.4
September 2012	0.0	1.8	3.5	5.3	1.8
October 2012	0.0	1.8	0.0	1.8	0.6

Rice et al (2011) sampled by trawl in deeper waters in estuaries and marine waters of Puget Sound. Within or near Elliott Bay, they sampled three sites, one on the north side by Piers 90/91 and two on the south side, the mouth of the Duwamish River and near Seacrest Park. Figure 9 shows the mean density of Chinook salmon from surface trawl samples within Elliott Bay. Juvenile Chinook salmon were found in deeper waters from May through October. Peak density of Chinook salmon in surface trawl samples in Elliott Bay were in June, one month later then peak densities found along the nearshore. This would indicate that Chinook salmon become less nearshore dependent as they grow larger.

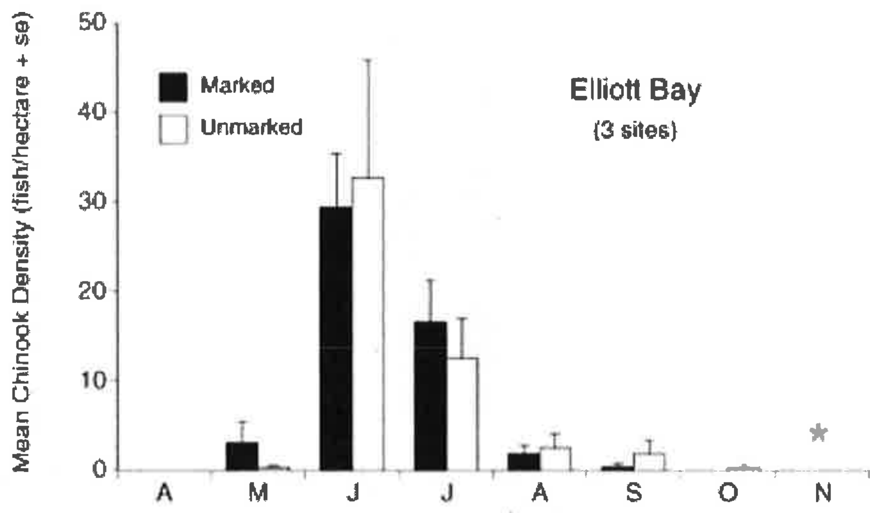

Figure 9. Mean + one standard error of marked and unmarked juvenile Chinook salmon within Elliott Bay in 2003 (Rice et al 2011).

The Green-Duwamish River Chinook salmon are a mix of wild and hatchery-produced fish. They are considered a healthy stock based on escapement levels (WDFW 2002c). Ford (2011) estimated the average number of natural (natural origin and hatchery) Chinook salmon spawners in the watershed was 3,077 between 2005 and 2009 with 56 percent contribution from hatcheries. The population trend and growth rate (lambda) of natural spawners between 1995 and 2009 was 0.952 indicating a shrinking population (Ford 2011). With hatchery fish contributing to the population, the growth rate for the Green River Chinook salmon population is 0.835. The lower growth rate with hatchery fish contribution may be related to density dependent effects, differences in spawning distribution relative to habitat quality, or reduced fitness of hatchery origin spawners (Ford 2011).

Approximately 20 to 30 percent of the Chinook salmon captured in Elliott Bay originated from the Skykomish River population (Nelson et al. 2004). The Skykomish River Chinook salmon population and the Snoqualmie River population are both located within the Snohomish River watershed. The Skykomish River Chinook summer/fall run population and the Snoqualmie River Chinook fall-run population are both rated depressed due to low stock productivity (WDFW 2002d, 2002e).

The estimated average number of natural (natural origin and hatchery) Chinook salmon spawners in the Skykomish and Snoqualmie Rivers were 3,334 and 888, respectively, between 2005 and 2009 with 14 and 11 percent contribution from hatcheries. The Skykomish River population trend and growth rate (lambda) of natural spawners between 1995 and 2009 was 1.036 indicating a slightly increasing population (Ford 2011). The lambda for the Snoqualimie River population was 0.99 indicating a stable population. With the small hatchery contributing to the population, the growth rate for the Skykomish and Snoqualmie Chinook salmon populations are 0.952 and 1.000, respectively.

Both the Green/Duwamish and the Skykomish river Chinook salmon minimum viability abundance number are 17,000 spawners (Ford 2011). Between 2005 and 2009, the average number of natural and hatchery spawners in the Green/Duwamish River was 3,077 fish, and for the Skykomish River, natural and hatchery spawners was 3,309.

The Chinook Salmon Recovery Team ranked each of the 22 Chinook salmon populations on their recovery potential. Factors included in the ranking included the status and structure of each population and their habitat (December 29, 2010, 75 FR 82208). Each population was ranked in one of three tiers. Tier 1 is essential for recovery, Tier 2 is important, and Tier 3 should not become extirpated if recovery actions are completed in the future. The Skykomish and Green/Duwamish river populations were ranked as Tier 2, and the Snoqualmie River population was ranked as Tier 3.

Juvenile Chinook salmon migrate out the Snohomish River beginning in late March and early April and continue through the end of July. Chinook salmon were caught within Possession Sound in early August (Beauchamp et al. 1987). Residence time within Possession Sound was 0 to 10 days. Hatchery released Chinook salmon from the Snohomish River watershed were captured in Elliott Bay 27 to 33 days after release from the hatchery. Travel distance from the mouth of the Snohomish River to Piers 90/91 is approximately 33 mi (53 km), indicating that the Chinook salmon are rapidly moving along the shoreline.

Of the remaining Chinook salmon populations found within the action area, the Lake Washington/Cedar River and the Stillaquamish River populations are both considered depressed, and the Puyallup River population status is unknown.

The nearshore areas in Puget Sound, including the action area, are essential to Chinook salmon conservation because they provide important rearing and migratory corridors. The nearshore environments are necessary for Chinook salmon to complete their life cycle because the protected waters provide forage and hiding places for Chinook salmon to grow and mature before continuing on to the ocean. Juvenile Chinook salmon experience the highest growth rates in the highly productive nearshore. Juvenile Chinook salmon using the action area for forage and rearing are mainly from the Green/Duwamish River and the Skykomish River. Even though the Elliott Bay shoreline is highly modified with riprap, bulkheads, piers, and seawalls, Chinook salmon forage, rear, and migrate within the action area. Adult Chinook salmon also use the action area as a migratory corridor to reach their natal streams. The action area near the mouth of the Duwamish River provides holding areas for adults prior to their migration upstream to spawn.

Chinook Salmon Critical Habitat

The NMFS designated critical habitat for the Chinook salmon on September 2, 2005 (70 FR 52630). One PCE for Chinook salmon critical habitat is located within the action area:

- PCE #5: Nearshore marine areas free of obstruction and excessive predation with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and

The current conditions of the nearshore PCE is described below:

Obstructions: The action area's nearshore is extensively modified with vertical seawalls, large overwater structures, and riprapped shoreline. Intertidal habitat that exists is limited to the eastern shore of Duwamish Head and the northern portion of Elliott Bay along the Olympic Sculpture Park and Myrtle Edwards Park. The seawalls and large overwater structures result in a migratory corridor with deep water and sharp contrast in light which Chinook salmon avoid. Chinook salmon migrate around all the overwater structures which increases predation risk. The City of Seattle is currently replacing the seawall and installing a habitat bench along the entire seawall to provide a shallow migratory corridor along the seawall. A cantilevered sidewalk with light penetrating surface is being installed to reduce sharp underwater light contrast caused by the overwater structures. The project is not expected to be completed until approximately 2020.

Water Quality: Water quality in Elliott Bay has been impaired by decades of various land use activities and discharges. Ecology and King County have ambient marine water quality monitoring stations in Elliott Bay. Industrial and commercial uses within the action area have resulted in releases of contaminated materials, stormwater, and combined sewer discharges. Heavy metals, phthalates, and PAHs are detected in most water quality samples in Elliott Bay. Dissolved oxygen levels within the action area range between 5.5 and 10 mg/L. Some lower levels of dissolved oxygen occur due to natural upwelling of low dissolved oxygen bottom waters.

Forage and Prey: With a lack of intertidal habitat within the action area, forage and prey species preferred by Chinook salmon is limited. The extensive seawall and overwater structures result in limited shallow water, uniform sediments, and variable light conditions that present an ongoing threat to the health of the benthic invertebrate community and food web in general (Windward Environmental 2010). The lack of intertidal habitat has reduced forage fish spawning within the action area. Sources of terrestrial prey are greatly diminished.

Natural Cover: The action area contains very little natural cover. The action area's nearshore is extensively modified with vertical seawalls, large overwater structures, and riprapped shoreline. The little natural cover that exists within the action area is limited to the restored shoreline of the Olympic Sculpture Park where large wood has placed and allowed to accumulate along the shoreline. Riparian vegetation is scarce, with a few ornamental trees in planter boxes along the seawall and scattered trees within Myrtle Edwards Park. A large number of trees exist along the

eastern shore of the Duwamish Head, but this vegetation is separated from Elliott Bay by Harbor Avenue which reduces or eliminates any potential riparian benefits to Elliott Bay.

Within the action area this PCE still functions, but is severely impaired

Bocaccio

Larval bocaccio are distributed by currents in Puget Sound (Drake et al. 2010). To what extent they are well distributed or occur in clusters reflecting the geography of reproductive adults is poorly understood. The best available data with which the Services could estimate the number of individuals in an action area is based on Greene and Godersky (2012). They sampled rockfish at six deepwater sediment disposal sites and 79 index sites. The index sites were chosen based on a number of criteria, including proximity to shorelines, depth, exposed shoreline, and degree of anthropogenic disturbance. The sites were selected to maximize spatial coverage of Puget Sound.

Sampling by Greene and Godersky (2012) occurred from April through October. Table 6 provides density estimates for rockfish within Elliott Bay at both the deepwater sediment site and the Duwamish index site.

Table 6. Rockfish densities within Elliott Bay (Greene and Godersky, 2012).

Month	Elliott Bay Deepwater Rockfish Density (fish/1,000 m^3)	Duwamish Index Site Rockfish Density (fish/1,000 m^3)
April	101.0	52.7
May	126.8	261.6
June	31.4	6.3
July	69.0	20.2
August	26.8	31.7
September	88.5	7.1
October	0	6.5

As they mature, bocaccio juveniles continue using the nearshore habitat (Love et al. 1991; Love et al. 2002; Yamanaka and Lacko 2001). Juvenile bocaccio use floating kelp habitat, which is found in those nearshore portions of the action area where sunlight reaches shallow water and boat traffic is limited. The relatively shallow bathymetry of the action area makes it extremely unlikely for adults to occupy the action area at any time. Adult bocaccio occupy deeper habitats with more complex bathymetry than occurs in the action area, so their presence is extremely unlikely.

Bocaccio Critical Habitat

The NMFS designated critical habitat for bocaccio on November 13, 2014 (79 FR 68041). Two PCEs for bocaccio critical habitat are located within the action area:

- Deepwater Critical Habitat: Adult bocaccio: Sites deeper than 98 feet (30 m) that possess (or are adjacent to) areas of complex bathymetry. These features are essential to

conservation because they support growth, survival, reproduction, and feeding opportunities by providing the structure to avoid predation, seek food, and persist for decades. Deepwater attributes include: 1) quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities; 2) water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities; and 3) structure and rugosity to support feeding opportunities and predator avoidance.

- Nearshore Critical Habitat: Juvenile bocaccio: Juvenile settlement sites located in the nearshore with substrates such as sand, rock, and/or cobble compositions that also support kelp. These features are essential for conservation because they enable forage opportunities and refuge from predators, and enable behavioral and physiological changes needed for juveniles to occupy deeper adult habitats. Nearshore attributes include: 1) quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities; and 2) water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities.

Quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities

Rockfish eat many different species of fish and invertebrates. The shoreline development within the action area has resulted in the degradation of some rocky habitat, loss of eelgrass and kelp, and a decrease in inter-tidal habitat important to spawning forage fish. This has resulted in the reduction in invertebrate and fish abundance and species diversity.

Water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities

Water quality in Elliott Bay has been impaired by decades of various land use activities and discharges. Ecology and King County have ambient marine water quality monitoring stations in Elliott Bay. Industrial and commercial uses within the action area have resulted in releases of contaminated materials, stormwater, and combined sewer discharges. Heavy metals, phthalates, and PAHs are detected in most water quality samples in Elliott Bay. Dissolved oxygen levels within the action area range between 5.5 and 10 mg/L. Some lower levels of dissolved oxygen occur due to natural upwelling of low dissolved oxygen bottom waters.

Structure and rugosity to support feeding opportunities and predator avoidance.

The northern and western portion of the action area contains the structure and rugosity to support feeding and predator avoidance. The deeper waters out from the project site do not contain structure and rugosity and is not designated critical habitat. Shoreline development has altered the nearshore and sediment delivery throughout the action area, that may have also altered or eliminated deepwater habitats.

Within the action area these PCEs still functions, but are severely impaired.

Southern Resident Killer Whales

The Whale Museum manages a long-term database of SR killer whale sightings and geospatial locations in inland waters of Washington. While these data are predominately opportunistic sightings from a variety of sources (public reports, commercial whale watching, Soundwatch, Lime Kiln State Park land-based observations, and independent research reports), SR killer whales are highly visible in inland waters, and widely followed by the interested public and research community. The dataset does not account for level of observation effort by season or location; however, it is the most comprehensive long-term dataset available to evaluate broad scale habitat use by SR killer whales in inland waters. For these reasons, NMFS relies on the number of past sightings to assess the likelihood of SR killer whale presence in the action area and during work windows.

The number of past sightings is provided in quadrates throughout Puget Sound, Hood Canal, and the Salish Sea. There are a total of 445 quadrates. Four quadrates are found within the action area for the project; 408, 409, 410, and 412. A very small portion of quadrate 413 is also in the action, and was excluded from analysis. A review of this dataset from the years 1990 to 2013 indicates that SR killer whales are observed in the action area during the months that in-water construction activities are proposed (Table 7).

Table 7. Southern resident killer whale sightings in the action area.

Month	Number of Days Sighted per Quadrate*				
	408	409**	410	412	Total
September	2	4	5	1	8
October	16	8	22	10	25
November	33	9	35	25	78
December	37	10	43	26	85
January	13	10	24	8	46
February	11	5	16	9	15
March	3	2	1	2	7

* Unique sighting days during the work window from 1990 to 2008.
** Quadrate where project is located.

Killer Whale Critical Habitat

The NMFS designated critical habitat for the killer whale on November 29, 2006 (71 FR 69054). Three PCEs for killer whale critical habitat are located within the action area:

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. Passage conditions to allow for migration, resting, and foraging.

Water quality to support growth and development

Water quality within the action area is degraded due to the highly developed areas surrounding Elliott Bay. Elliott Bay receives direct water runoff from several sources including CSO, stormwater, and vessel discharges, plus upland discharges that enter Elliott Bay through the Green/Duwamish River. Heavy metals, phthalates, and PAHs are detected in most water quality samples in Elliott Bay.

Prey species of sufficient quantity, quality and availability to support individual growth, reproduction and development, as well as overall population growth

Prey species, specifically Chinook salmon, within the action area originate from multiple watersheds throughout Puget Sound. Nearly 60 percent of Chinook salmon in the action area come from the Green/Duwamish River and 20 to 30 percent from the Snohomish River. The Green/Duwamish River stock of Chinook salmon is considered healthy but population trend and growth rates are declining. The Elliott Bay shoreline is highly modified with riprap, bulkheads, seawalls, and piers and may limit Chinook salmon foraging, rearing, and migration through the action area. Chemical contaminants in the water and sediments can enter the food chain through macroinvertebrates and accumulate in Chinook salmon.

Passage conditions to allow for migration, resting, and foraging

Vessel traffic from ferries, barges, container, and cruise ships increases underwater sound levels that can present obstacles to killer whale migration and communications. Ambient sound levels in the action area range from 123 dB_{RMS} to 141 dB_{RMS} (Laughlin 2011, 2015). Sound levels are loudest in the southern portion of the action area where ferry and container ship traffic is the highest. Increased sound levels may reduce the effective zone of echolocation and reduce availability of prey.

Humpback Whale

We have limited information about humpback whale foraging habits and space use in inside waters of Washington, and do not have specific fine-scale information for the action area. In recent years, humpback whales are sighted with increasing frequency in the inside waters of Washington, including Puget Sound (primarily during the fall and spring); however, occurrence is uncommon. On a few occasions, humpback whales have been recorded passing through Admiralty Inlet and into central Puget Sound through the action area during the in-water work window.

Bull Trout

Anadromous adult and subadult bull trout may utilize all marine waters of the action area for foraging, migrating, and overwintering. The extent of this utilization is poorly understood; however, Kraemer (1994) speculated that bull trout distribution in marine waters depends on the distribution of forage fish and their spawning beaches. Anadromous bull trout prey on surf smelt, Pacific herring, Pacific sand lance, juvenile salmonids, and other small schooling fish while in

the marine environment (Kraemer 1994; WDFW 1997). These prey species are present within the action area. Although foraging bull trout may tend to seasonally concentrate in forage fish spawning areas, they can be found throughout accessible estuarine and nearshore habitats.

Anadromous bull trout may seek and find more abundant forage in marine waters than in rivers (Kraemer 1994). As bull trout populations increase in abundance and competition for prey increases, individual bull trout may also forage more extensively and over greater distances in the marine environment (Chan, in litt. 2013). Kraemer (1994) also found bull trout in the marine environment as far as 40 kilometers (25 miles) from their natal stream. McPhail and Baxter (1996) documented a char traveling as far as 150 kilometers (93 miles) through marine waters from the Squamish River in British Columbia to the Skagit River in Washington.

We expect that some level of mixing or interaction within marine waters occurs among anadromous individuals from various core areas. Although studies have documented bull trout moving into non-natal rivers via marine waters (WDFW 1997; Goetz in litt. 2003), we do not understand the full extent of this behavior. On October 31, 2006, a 607 mm tagged bull trout was observed in the Snohomish River; by November 25, it migrated into the lower Duwamish River (approximately 35 mi [55 km]) where it stayed until the end of December (Goetz et al. 2012). The bull trout then migrated back to the Snohomish River by the end of January. The bull trout left the Duwamish River on December 27 and stayed within the action area until January 7, where it was located offshore of West Point, just north of Elliott Bay.

Based on these studies, anadromous bull trout from several different core areas may be present within the action area simultaneously. Marine areas within the action area are within foraging and migratory distances of the Stillaguamish, Snohomish-Skykomish, and the Puyallup River core populations. The Stillaguamish River and Puyallup River core areas are both ranked as "at risk," the Snohomish River core area is ranked as "potentially at risk" (USFWS 2008a). The number of bull trout that may be present in Elliott Bay and the marine environment of the action area are presumed to be related to the abundance of individuals in these core populations as well as the distance from the core area to the action area. More robust core populations such as the Snohomish-Skykomish are expected to utilize the marine environment in greater proportion than core populations that are extremely low in number. Puget Sound and the lower Green/Duwamish River are considered FMO habitat and do not have a spawning population (USFWS 2004a).

The number of bull trout that may be present in the action area, and specifically Elliott Bay, is believed to be small, but captures in the Duwamish River indicate that bull trout migrate through the action area. In April 1978, Dennis Moore, Hatchery Manager for the Muckleshoot Indian Tribe, talked with three anglers in the vicinity of North Wind Weir, river mile 7 of the Duwamish and identified four fish as adult char (Brunner 1999a). One adult bull trout was observed near Pier 91 in May 1998 (Brunner 1999b). In 2000, eight subadult bull trout were captured in the Duwamish River at the head of the navigation channel at the Turning Basin restoration site at river mile 5.3. These were subadult and adult fish that averaged 299 millimeters (11.8 inches) in length and were captured in August and September (Shannon 2001). A single char was caught at this same site in September of 2002 (USFWS 2004a). In May, 2003, an adult char (582 millimeters) was captured and released at Kellogg Island (USFWS 2004a). In a study conducted by Goetz et al. (2012) in 2006, tagged bull trout were monitored migrating

through Elliott Bay. A bull trout tagged in the Snohomish River migrated through Elliott Bay into the Duwamish River in November, and then migrated back out in December. One bull trout was observed on the newly installed habitat bench at the Olympic Sculpture Park in 2009 (Toft et al. 2010).

Subadult and adult bull trout use Elliot Bay for feeding, refuge, and as a migration route to other core areas or FMO habitat, even though habitat within Elliott Bay has been extensively modified, with approximately 97 percent of the original wetlands and shallow sub-tidal habitats filled (Kerwin and Nelson 2000). The substrate and sediment quality is poor due to contamination with PAHs, PCBs, and metals, the nearshore habitat is degraded by shoreline armoring and the presence of overwater piers and wharves, and less than 14 percent of shoreline supports riparian vegetation (primarily ornamental city trees), thereby reducing the complex habitat that large woody debris provides and is important to bull trout. Despite these significantly degraded conditions, the action area is a part of the bull trout migration corridor.

Conservation Role of the Action Area for Bull Trout

The action area is within the Coastal Recovery Unit (RU). Maintaining viable populations of bull trout is essential to the conservation of species within each of the core areas, the RU, and the conterminous listing. Marine waters of Puget Sound and FMO habitats are critical in supporting the bull trout anadromous life history form due to their complex migratory patterns associated with foraging and overwintering (USFWS 2015a, p. A-1, A-4). The marine waters provide important foraging habitat for prey species such as juvenile salmon, Pacific herring, surf smelt, and Pacific sand lance. In addition, the marine environment provides a migratory corridor for bull trout from their natal streams to other locations within Puget Sound or nearby watersheds to forage and overwinter.

Bull trout from three nearby core areas are expected to use the action area year round. The conservation role of the action area is to function as foraging, migration, and overwintering habitat necessary for bull trout recovery (USFWS 2004a, p. 20). Marine nearshore and estuarine habitats are highly productive due to the complexity of habitats and nutrient inputs (USFWS 2004a, p. 43).

The primary threat to the action area is continued development and urbanization that degrades or eliminates nearshore marine and estuarine habitats and processes critical to the persistence of the anadromous life history form and their marine prey base. Elliott Bay is essential to the recovery of bull trout within the three core areas, the Coastal RU, and the coterminous United States.

Bull Trout Critical Habitat

The USFWS designated critical habitat for bull trout on October 18, 2010 (75 FR 63898). The action area is used by anadromous bull trout at any time of the year for foraging and migration.

The current conditions of PCE's that are present in the action areas are described below.

PCE #2: Migration 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.

Elliott Bay's proper function as a migratory corridor is greatly diminished. Extensive shoreline development, extensive bank hardening, degraded riparian conditions, and a great many and wide variety of artificial overwater structures and encumberances present physical, biological, and water quality impediments to free movement and migration.

Within the action area this PCE still functions, but is severely impaired.

PCE #3: An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.

The action area provides foraging and rearing habitat for juvenile salmonids. Salmon populations include Chinook salmon, chum salmon (*O. keta*), coho salmon (*O. kisutch),* and sea run coastal cutthroat trout (*O. clarkia*), as well as other native and nonnative fishes, provide a sizable prey base for adult and subadult bull trout. However, the extensive seawall and overwater structures result in limited shallow water, uniform sediments, and variable light conditions that present an ongoing threat to the health of the benthic invertebrate community and food web in general (Windward Environmental 2010). Sources of terrestrial prey are greatly diminished.

Within the action area this PCE still functions, but is moderately impaired.

PCE #4: Complex river, stream, lake, reservoir, and marine shoreline aquatic environments, and processes that establish and maintain these aquatic environments, with features such as large wood, side channels, pools, undercut banks and unembedded substrates, to provide a variety of depths, gradients, velocities, and structure.

The action area exhibits greatly reduced habitat complexity and diversity. The shoreline of the action area, especially near the project site is almost completely developed. Since the early 1900s the shoreline has been modified to protect urban and industrial development. Overwater structures occupy over 65 percent of the Elliott Bay shoreline. The marine shoreline habitat function and complexity is substantially diminished compared to historic conditions.

Within the action area this PCE still functions, but is severely impaired.

PCE #5: Water temperatures ranging from 2 to 15 °C (36 to 59 °F), with adequate thermal refugia available for temperatures that exceed the upper end of this range. Specific temperatures within this range will depend on bull trout life-history stage and form; geography; elevation; diurnal and seasonal variation; shading, such as that provided by riparian habitat; stream flow; and local groundwater influence.

Water temperatures in the action area are highly influenced by tidal action and natural water circulation in Puget Sound. Water temperatures generally fluctuates between 7.7 °C (45.8 °F) and 16.4 °C (61.5 °F) (Ecology 2006).

Within the action area this PCE is properly functioning.

PCE #8: Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.

Water quality in Elliott Bay has been impaired by decades of various land use activities and discharges. Ecology and King County have ambient marine water quality monitoring stations in Elliott Bay. Industrial and commercial uses within the action area have resulted in releases of contaminated materials, stormwater, and combined sewer discharges. Heavy metals, phthalates, and PAHs are detected in most water quality samples in Elliott Bay.

Within the action area this PCE still functions, but is severely impaired.

Conservation Role of Bull Trout Critical Habitat in the Action Area

The conservation role of critical habitat for bull trout in the action area is primarily to support migrating and foraging bull trout while they are in the marine environment or migrating to freshwater FMO habitat in the Green/Duwamish River. The condition of water quality and the habitat in the action area influences several life history stages of bull trout, including adult and subadult bull trout. The USFWS considers all marine and estuarine waters and independent tributaries necessary for foraging, migration, and overwintering to be necessary habitat for bull trout in Puget Sound. The marine foraging, migration, and associated overwintering habitats are important for bull trout originating from the Puyallup River, Snohomish and Skykomish Rivers, and Stillaguamish River core areas for maintaining diversity of life history forms and for providing access to habitat that provides productive sources of prey.

Threats that need to be addressed in the action to ensure recovery include the impacts from shoreline development to critical habitat that reduce prey resources and habitat complexity. The intended recovery function of critical habitat is to support the core areas and ensure that the habitat requirements of bull trout are met, now and in the future. The migration habitat, prey base, habitat complexity, and water quality in action area have been degraded by development, a rising human population, industry infrastructure, and contaminants.

Climate Change

Our analyses under the ESA include consideration of ongoing and projected changes in climate. The terms "climate" and "climate change" are defined by the Intergovernmental Panel on Climate Change (IPCC). The term "climate" refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2014a, pp. 119-120). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2014a, p. 119).

Climate change affects listed marine mammals and listed fish species and their habitat throughout Washington. Several studies have revealed that climate change is affecting and will continue to affect salmonid habitat in nearly all tributaries throughout the state (Battin et al., 2007; ISAB 2007). While the intensity of effects will vary by region (ISAB 2007), climate change will generally alter aquatic habitat (water yield, peak flows, and stream temperature). As climate change alters the structure and distribution of rainfall, snowpack, and glaciers, these changes will alter riverine hydrographs. Climate and hydrology models project significant reductions in both total snow pack and low-elevation snow pack in the Pacific Northwest over the next 50 years (Mote and Salathé 2009). These changes will shrink the extent of the snowmelt-dominated habitat available to salmonids.

In Washington State, most models project warmer air temperatures, increases in winter precipitation, and decreases in summer precipitation. Average air temperatures in Washington State are likely to increase 0.1 to 0.6°C per decade (Mote and Salathé 2009). Warmer air temperatures will lead to more precipitation falling as rain rather than snow. As the snow pack diminishes, seasonal hydrology will shift to more frequent and severe early large storms, changing stream flow timing and increasing peak river flows, which may limit salmon survival (Mantua et al., 2009). The largest driver of climate-induced decline in salmon populations in projected to be the impact of increased winter peak flows, which scour the streambed and destroy salmon eggs (Battin et al., 2007).

High water temperatures and lower spawning flows, together with increased magnitude of winter peak flows are all likely to increase salmon mortality. Higher ambient air temperatures will likely cause water temperatures to rise (ISAB 2007). Salmon and steelhead required cold water for spawning and incubation. As climate change progresses and stream temperatures warm, thermal refugia will be essential to persistence of many salmonid populations. Thermal refugia are important for providing salmon and steelhead with patches of suitable habitat while allowing them to undertake migrations through or to make foraging forays into areas with greater than optimal temperatures. To avoid waters above summer maximum temperatures, juvenile rearing may be increasingly found only in the confluence of colder tributaries or other areas of cold-water refugia (Mantua et al., 2009).

Climate change will make recovery targets for these salmon populations more difficult to achieve. Habitat action can address the adverse impacts of climate change on salmon. Examples include restoring connections to historical floodplains and freshwater and estuarine habitats to provide fish refugia and areas to store excess floodwaters, protecting and restoring riparian vegetation to ameliorate stream temperature increases, and purchasing or applying easements to lands that provide important cold water or refuge habitat (Battin et al., 2007; ISAB 2007).

Climate change will also affect listed marine species. Effects from climate change in the marine environment include increased ocean temperature, increased stratification of the water column, and changes in intensity and timing of coastal upwelling. Direct studies on the effect of climate variability on rockfish are rare, but all the studies performed to date suggest that climate plays an extremely important role in population dynamics (Drake and Griffen 2010). Although the mechanism by which climate influences the population dynamics of rockfish remains unknown, several authors have reported negative correlations between the warm water conditions

associated with El Niño and the population dynamics of rockfish (Moser et al., 2000). Field and Ralston (2005) reported that recruitment in all species of rockfish appeared to be correlated at large scales and hypothesized that such synchrony was the result of large-scale climatic phenomena. Tolimieri and Levin (2005) reported that bocaccio recruitment off California is correlated with specific sets of climate patterns. These phenomena are also believed to affect the population dynamics of Puget Sound/Georgia Basin yelloweye rockfish.

Effects of climate change will alter primary and secondary productivity, the structure of marine communities and, in turn, the growth, productivity, survival, and migrations of salmonids. A mismatch between earlier smolt migrations (due to earlier peak spring freshwater flows and decreased incubation period) and altered upwelling may reduce marine survival rates. Increased concentration of carbon dioxide reduces the availability of carbonate for shell-forming invertebrates, including some that are prey items for juvenile salmonids and rockfish species. In each of these cases, the specific effects on salmon and steelhead abundance, productivity, spatial distribution and diversity are poorly understood, but as a primary prey source for SRKWs, the effect on salmonids from climate change has potential to affect prey abundance as a PBF of SRKW critical habitat. Humpback whales primarily eat zooplankton and forage fish, but, to the degree that salmonids are prey of humpback whales, climate change is expected to negatively affect salmon as prey for humpbacks as well. Climate change could also indirectly affect humpback whales through trophic dynamics and available non-salmonid prey.

Previously Consulted-on Projects within the Action Area

The following information on projects consulted on within the action area was obtained from the USFWS' Tracking and Integrated Logging System and NMFS' Project Consultation and Tracking System. Both NMFS and the USFWS would have consulted on the same projects, however, the effects to the species and the final effects determination may be different for each project.

Since 2007, the USFWS has consulted on 42 projects within the action area; two of these projects were formal consultations, and 40 were informal consultations. NMFS consulted on 79 projects within the Fifth Field HUC (1711001994) in which the action area occurs only in a small portion. Most of the projects had one or two years of construction, which are expected to now be complete. For the most part, these projects maintained the degraded baseline conditions of dense overwater strucutures within the action area by replacing damaged piles on dolphins and existing piers. However, those that added grated decking and/or replaced creosote piles with steel piles may have some localized benefit to water quality, vegetation, and benthic invertebrates. Other projects where effects were insignificant or discountable included outfall extensions, dredging, and marina breakwater and slip modifications.

The Services consulted on eight projects where construction may be occurring simultaneously with the proposed action or the projects may have long-term effects to listed fish species within the action area. Four projects involve installation of piles with either a vibratory, impact, or a combination of both pile drivers. Construction of the Seawall Replacement Project involves the use of two pile drivers. The Colman Dock Project includes the use of three pile drivers. Effects to Chinook salmon, bocaccio, and bull trout from these two projects included injury and

mortality due to exposure to elevated sound pressure levels from impact pile driving. The projects involving the use of vibratory pile drivers were determined to have insignificant effects on Chinook salmon, bocaccio, and bull trout. However, added together, these projects may result in important behavioral changes, such as changes in feeding, avoidance of preferred habitats, and delays in, or alteration of, migratory movements, within the action area.

2.5 Effects of the Action

Under the ESA, "effects of the action" means the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.

This opinion addresses two separate but related actions: (l) the COE's issuance of a permit to Seattle Parks and Recreation for the replacement of Pier 62, (2) NMFS' issuance of an IHA under Section 101 (a)(5)(D) of the MMPA, and the underlying activity which is the basis for these requested federal approvals. The effects of authorizing the underlying action are addressed below.

Shade Caused by Moorage and Overwater Structures

The Services analyzed the effects of shading from replacing the pier superstructure, the new float dock and gangway, and the removal of overwater structure. The proposed action, will remove approximately 43,203 square feet of solid overwater structure; approximately 36,900 square feet from Pier 62, 3,874 square feet from the west end of Pier 63, and 2,429 square feet along the nearshore of Pier 63. The replacement superstructure will be 1,372 square feet smaller and will have approximately 4,757 square feet of grating installed along the nearshore; approximately 2,328 square feet on Pier 62 and 2,429 square feet on Pier 63. The new floating dock and gangway, along the south edge of Pier 62, is approximately 3,480 square feet. Overall, the project reduces overwater structure by 715 square feet and increases light penetration under the superstructure by replacing 4,757 square feet of current solid structure with grating.

Effects of Shade

The Services largely relied on the work of Simenstad et al. (1999) and Nightingale and Simenstad (2001a), for the most current synthesis on the effects of piers on salmonid behavior, habitat, and predation. The report summarizes effects of overwater structures with an emphasis on ocean-type juvenile salmonids (30 to 60 mm in size), as well as larger juvenile salmonids, like sockeye (*O. nerka*), coho (*O. kisutch*), and steelhead.

The Simenstad et al. (1999) and Nightingale and Simenstad (2001a) literature syntheses concluded the following:

1. Overwater structures create sharp, underwater light contrasts by casting shade over an area during the day. Light contrasts can also occur at night from artificial lighting surrounding a structure.

2. Fish exposed to sharp, underwater light contrasts may be exposed to increased risk of mortality as a consequence of the following: delays in migration from disorientation caused by lighting changes, loss of schooling refugia (protection) due to fish school dispersal under limited light conditions, and a change in migratory routes to deeper waters, which lack refugia from predators.

3. No studies are available that provide empirical evidence supporting or refuting the hypothesis that modification of juvenile salmonid behavior in shoreline habitats resulted in changes in survival. Results were exceedingly variable and appeared to reflect the study conditions (e.g., adjacent shorelines, dock dimensions and material, artificial lighting, etc.) that affected observations.

4. Despite considerable speculation that overwater structures increase the numbers and success of predatory fish, evidence supporting this contention is inconclusive. Quantitative assessment of predation around overwater structures is meager, and few studies have confirmed actual predation.

5. Light is extremely important in determining the type and distribution of diatoms, photosynthetic bacteria, phytoplankton, macroalgae, microalgae and seagrasses. Overwater structures can reduce light levels by 90 to 100 percent below ambient, which can significantly affect marine plant distribution and abundance.

Nightingale and Simenstad (2001a) concluded that cumulative impacts of overwater structures in urban industrialized areas in estuaries (multiple placements of overwater structures) can pose substantive risks to estuarine ecosystems, especially in areas like Elliott Bay where estuarine habitat is extremely limited and the shoreline is highly modified with piers and bulkheads. Both syntheses suggested using a landscape ecology approach to address cumulative impacts by combining increased light in under-pier environments with adjacent areas of enhanced prey production. This approach would begin to rebuild a migratory corridor with a higher carrying capacity for juvenile salmonids that typically suffer high mortality during migration.

These literature syntheses suggest that the habitat value under overwater structures will be very low. Light levels below overwater structures will significantly limit or eliminate primary production, thus leading to a less diverse community structure. Habitat surveys along the existing seawall have found low productivity under the existing piers (see Section 2.3, Environmental Baseline). Juvenile salmonids were also found not to migrate under piers or cross the shadeline created by the overwater structures (Brown et al. in litt. 2011).

Overall, the project will reduce overwater structure by 715 square feet and increases light penetration under the superstructure by replacing 4,757 square feet of current solid structure with grating. With grating being installed along the first 26 feet of both Piers 62 and 63, and the new habitat bench being constructed for the Seawall Replacement Project, the Services expect that the

project will benefit the migratory behavior of listed fish species. The grating and light penetrating surface installed over the habitat bench will improve the migratory corridor between Piers 62 and 63 and the seawall. While the amount of overwater structure is reduced, the Services anticipate that shade from the superstructure will have no more than minor effects to Chinook salmon, bocaccio, and bull trout. The overall effects of the project including the benefitial effects of the reduced size of the overwater structure and the grating installed along the nearshore, and the effects of the shade due to the overwater structure to Chinook salmon, bocaccio, and bull trout are considered insignificant. Although the effects of shade from the replacement of the pier are considered insignificant, the effects are considered and addressed in the remainder of this analysis, particularly the Integration and Synthesis portion of the opinion."

Water Quality

The City will be installing a sediment curtain around all construction activities. The sediment curtain will avoid and minimize increased contaminant (creosote), turbidity, and suspended sediment exposure to juvenile Chinook salmon and bocaccio. The City was unable to provide specifics on where the sediment curtain will be installed and how often the sediment curtain will be opened to allow barges to enter and exit. Therefore, the Services analyzed the project both with the sediment curtain installed to estimate entrapment risk and without the use of a sediment curtain in order to estimate risk of exposure to water quality impacts.

Contaminants - Creosote

The proposed project involes the removal of 880 creosote-treated timber piles. PAHs associated with creosote-treated wood can contaminate surrounding sediment up to 2 meters from the pile (Evans et al. 2009). The removal of the creosote-treated piles can mobilize these PAHs into the surrounding water and sediments (Smith 2008; Parametrix 2011). The concentration of PAHs released into surface water rapidly dilutes. Smith (2008) reported concentrations of total PAHs of 101.8 micrograms per liter (µg/L) 30 seconds after creosote-pile removal and 22.7 µg/L 60 seconds after removal; however, PAH levels in the sediment after pile removal can remain high for 6 months or more (Smith 2008). Romberg (2005) found a major reduction in sediment PAH levels 3 years after pile removal contaminated an adjacent sediment cap.

There are two pathways for PAH exposure to listed fish species in the action area: direct uptake through the gills and dietary exposure (Lee and Dobbs 1972; Neff et al. 1976; Karrow et al. 1999; Varanasi et al. 1993; Meador et al. 2006; McCain et al. 1990; Roubal et al. 1977). Fish rapidly uptake PAHs through their gills and food, but also efficiently remove them from their body tissues (Lee and Dobbs 1972; Neff et al. 1976). Juvenile Chinook salmon and bocaccio prey include amphipods, copepods, and fish larvae. The prey species uptake PAHs from contaminated sediments; the PAHs bioaccumulate in their tissues and cause greater levels of contamination in predator fish species (Landrum and Scavia 1983; Landrum et al. 1984; Neff 1982).

The primary effects of PAHs on Chinook salmon and bocaccio are immunosuppression and reduced growth. Karrow et al. (1999) characterized the immunotoxicity of creosote to rainbow trout (*O. mykiss*) and reported a lowest observable effect concentration for total PAHs of 17

μg/L. Varanasi et al. (1993) found greater immune dysfunction, reduced growth, and increased mortality compared to control fish. Consumption of contaminated prey, rather than absorption from the water, probably represents the primary pathway of contamination in marine fishes, such as rockfish (West and O'Neill 1998). Physiological effects of PAH exposure on Puget Sound fish include liver cancer, reproductive impairment, reduced immune function, and suppressed growth (Johnson et al. et al., 2008).

Juvenile Chinook salmon and bocaccio that currently use the habitat near Pier 62 are likely to be exposed to PAHs. The magnitude of the exposure will greatly increase during the removal of these structures. Because PAHs are associated with sediments, the Services expect increased PAHs in the water column to extend 15 meters (50 feet) from sediment generating activities. Some of the Chinook salmon and bocaccio exposed to PAHs from the proposed action will experience immunosuppression and reduced growth that, in some cases, will increase the risk of death. The removal of the creosote-treated timber will reduce listed-fish exposure to PAHs in the long term.

Elevated Turbidity and Suspended Sediment

In-water construction to remove the 880 creosote-treated timber piles and the vibratory installation of 189 steel piles will cause episodes of turbidity and suspended sediment. Juvenile Chinook salmon, bocaccio, and bull trout will be exposed to elevated turbidity and suspended solids. Chinook salmon and bocaccio are more nearshore dependent as juveniles. Juvenile Chinook salmon migrating along the nearshore are feeding on a variety of invertebrates; the juvenile bocaccio are found in shallow waters near algae, seagrass, and kelp where they benefit from warmer temperatures, food, and refuge from predators; and bull trout occur where prey species are readily available, which can include the project area.

Within the action area, and specifically along the Seattle Seawall, nearshore currents are generally low and run parallel to the waterfront (SDOT 2012b), and they are generally insufficient to re-suspend and transport its fine silts and clay sediment (Curl et al. 1988). Between and under the piers, the currents are weaker and of mixed direction. Wind-driven waves and waves from shipping traffic hit the vertical seawall and release energy at depth that can cause re-suspension of sediments, especially during low tides and winter storm events. Based on these conditions, construction activities will cause temporary increases in turbidity and suspended solids during pile removing and installation.

Fish Responses to Turbidity and Suspended Sediment. The variety of effects that fish experience when they encounter suspended sediment may be characterized as lethal, sublethal, or behavioral (Bash et al. 2001; Newcombe and MacDonald 1991; Waters 1995). Lethal effects to salmonids in marine waters include gill trauma (physical damage to the respiratory structures) (Curry and MacNeill 2004) and reduced prey due to smothering of forage fish eggs and macroinvertebrates (Chapman 1988). Sublethal effects include physiological stress reducing the ability of fish to perform vital functions (Cederholm and Reid 1987), severely reduced respiratory function and performance (Waters 1995), increased metabolic oxygen demand (Servizi and Martens 1991), susceptibility to disease and other stressors (Bash et al. 2001), and reduced feeding efficiency (Newcombe and MacDonald 1991). Sublethal effects can act separately or cumulatively to

reduce growth rates and increase fish mortality over time. Behavioral effects include avoidance and related secondary effects to feeding rates and efficiency (Bash et al. 2001). Fish may be forced to abandon preferred habitats and refugia, and may enter less favorable conditions and/or be exposed to additional hazards (including predators) when seeking to avoid elevated concentrations of suspended sediment.

A summary of effects from suspended sediment is listed in Table 8, and a more detailed discussion of effects (specific to bull trout, but relevant to all salmonids) is included in Appendix A.

Table 8. Summary of the adverse effects of sediment on fish.

Sediment Impacts to Fish	Summary of Adverse Effects Related to Sediment Impacts
Gill trauma	Clogs gills which impedes circulation of water over the gills and interferes with respiration
Prey base	Disrupts both habitat for and reproductive success of macroinvertebrates and other salmonids (bull trout prey) that spawn and rear downstream of the construction activities
Feeding efficiency	Reduces visibility and impacts feeding rates and prey selection
Habitat	Fills pools, simplifies and reduces suitable habitat
Physiological	Increases stress, resulting in decreased immunological competence, growth and reproductive success
Behavioral	Results in avoidance and abandonment of preferred habitat

In the nearshore environment, where important maturation and development of migrating juvenile Chinook salmon occurs, turbidity avoidance can force movement into deeper waters where the ratio of feeding opportunity to predation risk is reduced. The responses of bocaccio are likely to be different from the responses of Chinook salmon because of the life stages that inhabit the nearshore environment. Larval bocaccio occupy the nearshore and are distributed by currents while juveniles are associated with kelp.

The Services expect that all individuals of Chinook salmon and bocaccio that are within 15 meters (50 feet) of in-water construction activities will respond with significant disruption in normal behaviors, such as increased stress leading to reduced ability to perform vital functions such as feeding, migrating, or avoidance of predators, resulting from increased turbidity and suspended solids. The 15-meter (50-foot) distance for impacts to listed fish species is based on Weston Solutions (2006) and Shepsis (in litt. 2012). Weston Solutions and Pascoe Environmental Consulting (2006) monitored pile removal activities in Lower Sequim Bay. Removal of timber piles with a vibratory pile driver resulted in localized increased turbidity levels within 5 to 10 meters (16.4 to 32.8 feet). Shepsis (in litt. 2012) modeled current velocities at Colman Dock along the seawall and found tidal flow circulation velocities to be very low and are not a significant factor in sediment transport processes. The Services assume that increased turbidity and suspended sediment levels will dissipate to background levels within 15 meters (50 feet) of sediment generating activities.

Chinook Salmon Exposure to Contaminants, Turbidity, and Suspended Sediments. Sediment generating activities include the removal and installation, both vibratory and impact driving, of piles. In-water construction will occur between September 1, 2017, and February 28, 2018, the first construction season, and September 1, 2018 to February 28, 2019, the second season. Pile removal and installation could occur throughout both in-water work seasons. Juvenile Chinook salmon found along the seawall in September and October (
Figure 8, Toft, in litt. 2013a), will be exposed to elevated contaminants, turbidity, and suspended sediment levels.

The average number of Chinook salmon captured along the three seawall sites was 1.8 fish/520 m^2 in September and 0.6 fish/520 m^2 in October (Table 5, UW unpublished data). Residence time for Chinook salmon in Elliott Bay was found to average 18.4 days, ranging from 2 to 52 days during June and July (Ruggerone and Volk 2004). The City estimated that pile removal will take 49 to 74 days and installation will take 53 to 80 days. A total of 880 piles will be removed, averaging 12 to 18 piles per day. The Services estimate that each of the 880 wood piles is approximately 4 feet from each other. Assuming that the piles will be removed in sections (i.e., a 6 pile by 6 pile grid), the total area around this grid where increased contaminants, turbidity, and suspended sediments will result in significant disruption in normal Chinook salmon behavior, injury, or mortality is 14,400 square feet (1,338 square meters). This is a worst case scenario because some of this area will be under that portion of the pier yet to be removed, or may be under Pier 63 which is not being replaced. The Services estimate that up to four juvenile Chinook salmon per day in September and two in October will have disruption in normal behavior, injury, or mortality as a result of increased contaminants, turbidity, and suspended solids from pile removal. Similarly, with 4 piles being installed per day, the area of increased contaminants, turbidity, and suspended sediments will be similar to that of piles being removed as the installed piles are further apart (approximately 14 feet). Juvenile Chinook salmon are not expected to be found within the project area between November and the end of February and therefore, will not be exposed to increased contaminants, turbidity, and suspended solids from pile removal and installation during the winter time frame. The four juvenile Chinook salmon per day in September and two in October with significant disruption in normal behaviors, injury, or mortality from increases in contaminants, turbidity, and suspended sediments equals 156 juveniles in 2017 and 156 in 2018 (assuming a 6 day work week, and pile removal and installation occurs each work day from September 1 through October 31, 2017, and September 1 through October 31, 2018).

Bocaccio Exposure to Contaminants, Turbidity and Suspended Sediments. For the purpose of this analysis, we refer to larval and pelagic juvenile rockfish as "larvae" because there is no clear delineation between these life stages, and each would be similarly affected by this effect of the proposed action. Larval rockfish have been documented in Elliott Bay (Greene and Godersky, 2012). In addition, some larvae and pelagic juveniles of ESA-listed rockfish broadly disperse from the area of their birth (NMFS 2003, Drake et al., 2010) and are likely to be using habitat in the action area during project construction activities.

Using the shallow water Duwamish index site from Greene and Godersky (2012), larval rockfish densities in Elliott Bay in September and October were estimated at 7.1 and 6.5 rockfish per 1,000 m^3 (35,315 ft^3), respectively. Rockfish larvae are difficult to identify from morphological

features alone until they are several weeks to months old (Love et al., 2002), thus Greene and Godersky (2012) did not identify species. To estimate the abundance of rockfish larvae that would be in the project area when increased sediment and turbidity are expected, we used the densities of all rockfish larvae reported in Greene and Godersky, (2012), and bounded it by the proportion of bocaccio caught in the recreational fisheries (WDFW 2010).

For the purposes of this analysis, we assume that the proportion of ESA-listed rockfish caught by recreational anglers compared to the total rockfish caught roughly represents the proportion of larval rockfish. The proportion of adult bocaccio caught by recreational anglers from 2004 to 2008, as a proportion of the total rockfish catch, was 0.00026 percent of the total rockfish caught (WDFW 2010). By multiplying the percentage of the recreational catch by the density reported by Greene and Godersky (2012), we derive the estimated densities of bocaccio larvae within Elliott Bay. This calculation results in an estimated density of 0.00002 bocaccio larvae per 1,000 m^3 (35,315 ft^3) in September and October. The volume of water impacted by increased contaminants, turbidity, and suspended solids from construction is approximately 2,610 m^3 (92,171 ft^3). Values used are:

- 6 meters (20 feet) average depth of water along seawall (SDOT 2012e)
- 15 meters (50 feet) estimated length of increased contaminants, turbidity, and suspended solids from project
- 29 meters (96 feet) for the width of Pier 62.

Therefore the number of bocaccio larvae that may be impacted by increased contaminants, turbidity, and suspended solids is 0.00005 per day in both September and October. Because of these very low numbers, the Services estimate that one larval bocaccio per year will have significant disrupted behavior, injury, or mortality as a result of the increased contaminants, turbidity, and suspended solids during pile removal and installation during the months of September and October.

Bull Trout Exposure to Contaminants, Turbidity and Suspended Sediments. The disruption in normal behaviors, injury, or mortality described above will result from turbid conditions, which included increased contaminants, caused by pile removal and installation in the autumn months. Since adult and subadult bull trout are highly mobile and can easily avoid or quickly pass through turbidity plumes, this species will not be significantly affected by exposure to elevated contaminant, turbidity, and sediment sediment levels during project construction, especially because at this life-history stage, they are less susceptible to injury when exposed to turbidity. As such, the effects to bull trout due to short-term exposure to elevated levels of contaminants, turbidity, and suspended sediments associated with the proposed action are considered insignificant. Although the effects of elevated levels of contaminants, turbidity , and suspended sediments are insignificant, the effects are considered and addressed in the remainder of this analysis, particularly the Integration and Synthesis portion of the opinion.

Fish Isolation and Exclusion

The following analysis was conducted to estimate the number of juvenile Chinook salmon and bocaccio that will be killed as a result of the installation and use of a sediment curtain.

In-water construction will occur between September 1 and February 28 in both the first construction season (2017-2018) and second (2018-2019). The installation of the sediment curtain will occur one to two weeks prior to the start of in-water work, but not before September 1. The sediment curtain will be installed between 10 and 200 feet from construction activities depending on curtain location and barge use. In locations where a barge will not be used (west end of Piers 62/63 and north of Pier 63), the sediment curtain will be installed close to the construction activities. On the south side of Pier 62, where barge activity will occur, the sediment curtain may be installed up to 200 feet from Pier 62. To allow for barges to enter and exit the construction site, the contractor will remove a seam or a panel from the sediment curtain that will allow barges to pass through the sediment curtain. For smaller boats, the boat operator will tilt up the motor and float over the sediment curtain.

Because juvenile Chinook salmon and bocaccio will be along the seawall in September when the sediment curtain is installed, a number of Chinook salmon and bocaccio will be trapped within the sediment curtain. The Services expect that all Chinook salmon and bocaccio trapped within the sediment curtain will be killed from exposure to increased turbidity, suspended sediments, and sound pressure levels. In addition, if the sediment curtain is opened at any time in September and October to allow barges to enter and exit, Chinook salmon and bocaccio may enter and be trapped within the sediment curtain. The City was not able to provide any information on how often this will occur. Therefore, we were unable to estimate the total number of Chinook salmon or bocaccio that may be captured within the sediment curtain throughout its use.

To determine the area within the sediment curtain, the Services assumed the sediment curtain will be installed 200 feet along the south side of Pier 62, and within 10 feet along the west side of Piers 62/63 and north side of Pier 63 where no work will occur. The area under the piers was also subtracted from the total area as few, if any, Chinook salmon and bocaccio will be found under the piers. The area within the sediment curtain is approximately 91,089 square feet. (8,462 square meters).

Chinook Salmon Trapped within the Sediment Curtain. Juvenile Chinook salmon are found along the seawall in September and October (
Figure 8, Toft, in litt. 2013a). During fish surveys, the average number of Chinook salmon captured along three seawall sites was 1.8 fish/520 m^2 in September and 0.6 fish/520 m^2 in October (Table 5, UW unpublished data). Residence time for Chinook salmon in Elliott Bay was found to average 18.4 days, ranging from 2 to 52 days during June and July (Ruggerone and Volk 2004). The total area within the sediment curtain (200 feet on the south side and 10 feet on the west and north sides of Pier 62/63), minus the area of the existing piers is 91,089 square feet (8,462 square meters). The Services estimate that up to 29 juvenile Chinook salmon (58 total over 2 years) may be trapped within the sediment curtain when it is installed in September of each construction season. These juvenile Chinook salmon will be killed due to increased turbidity, suspended sediments, and sound pressure levels during construction. The total number of Chinook salmon trapped within the sediment curtain may be higher depending on the number of times and for how long the sediment curtain is opened in September and October to allow for barges to enter and exit. An unknown number of Chinook salmon may enter the project area when the sediment curtain is open.

Bocaccio Trapped within the Sediment Curtain. Using the calculation above under Bocaccio Exposure to Turbidity and Suspended Sediments, the volume of water enclosed within the sediment curtain is 1,821,780 square feet (50,772 square meters). The Services estimate that 0.001 bocaccio larvae may be trapped within the sediment curtain when it is installed in September of each construction season. Because of the very low number, the Services estimate that one larval bocaccio per year (two total over 2 years) will be trapped within the sediment curtain and will be killed due to increased turbidity, suspended sediments, and sound pressure levels during construction.

Bull Trout Trapped within the Sediment Curtain

Bull trout use the marine nearshore for migration and foraging. Sub-adult and adult bull trout are found along the nearshore in the vicinity of prey species which include juvenile salmonids. One bull trout was observed on the habitat bench along the Olympic Sculpture Park in 2009 and several radio-tagged bull trout moved between the Snohomish River and the Duwamish River, indicating that they may be present in low numbers any time of the year. The Services do not expect bull trout to be trapped within the sediment curtain.

Exposure to Elevated Underwater Sound Pressure Levels

Sound Metrics and Key Terms

- Amplitude: measurement of the acoustic energy of sound vibrations. Sound amplitude is measured on a logarithmic scale in units called decibels.
- Decibel (dB): a numerical expression of the relative loudness of a sound.
- Decibel A-weighted (dBA): measurement for in-air sound pressure, which approximates human hearing, referenced to 20μPa.
- Frequency: the rate of oscillation or vibration of sound measured in cycles per second, or hertz (Hz). Ultrasonic frequencies are those that are too high to be heard by humans (greater than 20,000 Hz); and infrasonic sounds are too low to be heard (less than 20 Hz).
- Leq: measurement of in-air value of a sound of objects moving along a linear corridor over an extended period of time. Sound value is an average value over a stated time interval. Measurement of a linear source noise such as a highway or ambient sound levels at a given location.
- Lmax: maximum or highest in-air value of a sound pressure over a stated time interval. Measurement of a point source noise such as a construction site.
- Practical Spreading Model: used by the Service to estimate the distances at which injury and behavioral disruption are expected. The Practical Spreading Model assumes that SPLs decrease at a rate of 4.5 dB per doubling of distance in the underwater environment. This opinion assumes transmission loss occurs from practical spreading of sound as

described by Davidson (2004) and Thomsen et al. (2006) [TL = 15*Log(R)] where R is the range or distance the sound extends from the source.

- Reference pressure: the pressure value used in calculating SPLs in dB. This document refers to both underwater and in-air SPLs. Underwater sounds are referenced to 1μPa. In-air sounds are referenced to 20μPa.
- Sound: vibrations in air or water that stimulate the auditory nerves and produce the sensation of hearing. The perception of a sound depends on two physical characteristics – amplitude and frequency, both of which can be measured.
- Sound pressure levels (SPL): sound pressure that is expressed in dB. In this document, underwater SPLs are referred to in units of dB re: 1 μPa and are denoted as dB.
  - Peak pressure (peak): the highest level or amplitude or greatest absolute sound pressure level during the time of observation. Sound pressure levels expressed as peak are used in discussing injury or mortality to aquatic species.
  - Sound exposure level (SEL): a metric that incorporates both sound pressure level and duration. SEL is calculated as 10 times the logarithm of the integral, with respect to duration, of the mean-square sound pressure, referenced to μPa^2-sec. Using this metric, 0-dB SEL corresponds to a continuous sound whose root mean square sound pressure equals the reference pressure of 1 μPa at a duration of 1 second (Morfey 2001, p. 347).
  - Root Mean Squared (RMS): is root square of the energy divided by the duration. Sound pressure levels expressed as RMS are commonly used in discussing behavioral effects. Behavioral effects often result from auditory cues and may be better expressed through averaged units than by peak pressures.
- Transmission loss (TL): the loss of sound energy as sound passes through a medium such as water. Several factors are involved in TL including the spreading of the sound over a wider area (spreading loss), losses to friction (absorption), scattering and reflections from objects in the sound's path, and interference with one or more reflections of the sound off of surfaces (in the case of underwater sound, these surfaces are the substrate and air-water interface. Transmission loss in air occurs from contact with landforms, trees or buildings).

In-Water Sound

The project involves pile removal with a vibratory pile driver and pile installation conducted to the maximum extent with a vibratory pile driver with impact pile driving for proofing. Replacement of Pier 62 will require the installation of 180 steel piles, 30-inches in diameter, and installation of nine steel piles, 30-inch diameter, is necessary to provide structural support to the end of Pier 63. Proofing will require 20 strikes per pile with four piles per day being installed. For impact pile driving, a "soft-start" will be used as a minimization measure to protect marine mammals. At the start of impact pile driving, an initial set of three strikes from the impact

hammer at reduced energy will be conducted, followed by a one-minute waiting period, then two subsequent three-strike sets. The remaining strikes will then occur.

The Services estimated the area around each pile where fish are considered at risk of injury or behavioral disruption during pile driving based on expected source sound levels and by factoring transmission loss. The City provided expected sound levels that could be generated by the proposed pile driving associated with the project. The City used attenuated noise levels for 36-inch piles from the Colman Dock Test Pile Project conducted in 2016 (WSDOT 2016b). Attenuated noise levels are 205 dB_{peak}, 176 dB_{SEL}, and 189 dB_{RMS}. The City will be using a bubble curtain to attenuate sound pressure levels, and since the levels used in their estimates are attenuated values, hydroacoustic monitoring is necessary to verify these values (i.e. that the amount of expected attenuation is what actually happens at the site). The City will also be using two pile drivers to remove and install piles. Operating multiple noise sources at the same time results in a louder noise than one source alone (WSDOT 2017, p. 7.15-7.16), so the noises can be added together to provide a more realistic source level of the sound for calculating the potential effects on marine mammals. Because of the number of piles and pile strikes to be installed per day with an impact driver is small (4 piles and 20 strikes per pile [20 strikes will occur within approximately 30 seconds, excluding the slow startup for minimizing impacts to marine mammals]), the Services assumed that two impact piles drivers will not be used at the same time, and if they did, the probability of both drivers impacting at the same time would be extremely low. Therefore, we did not increase the source sound levels for multiple pile drivers operating at the same time (WSDOT 2017, p. 7.15-7.16).

Behavioral Responses of Fish to Elevated Underwater SPLs

Behavioral responses to high underwater SPLs vary. Examples of typical behavioral effects include displacement, increased vulnerability to predation, interrupted feeding, or delayed migration. However, many response behaviors have not been thoroughly studied. Further confounding the issue, most of the information on behavioral effects of underwater sound is obtained from studies examining pure tone sounds.

Sounds generated by impact pile driving are impulsive and are made up of multiple frequencies/ tones, making comparisons with existing data difficult. Most of the sound energy of impact pile driving is concentrated at frequencies between 100 and 800 Hz. Salmonids can detect sounds at frequencies between 10 Hz (Knudsen et al. 1997) and 600 Hz (Mueller et al. 1998). Optimal salmonid hearing is thought to be at frequencies of 150 Hz (Hawkins and Johnstone 1978). Therefore, impact pile installation produces sounds within the range of salmonid hearing.

Popper (2003) notes that behavioral response of fishes to loud sounds could either include swimming away from the sound source (decreasing potential exposure to the sound); or staying in place (becoming vulnerable to possible injury). Responses to sound could also affect behavior more extensively, resulting in fish leaving a feeding ground (Engas et al. 1996) or an area where it would normally reproduce. Feist et al. (1992) found that impact pile driving of concrete piles affected juvenile pink and chum salmon distribution, school size, and schooling behavior. In general, on days when pile driving was not occurring, the fish exhibited a more polarized schooling behavior (moving in a definite pattern). When pile driving was occurring, the fish

exhibited an active milling schooling behavior (moving in an eddying mass). Fish appeared to change their distributions about the site, orienting and moving towards an acoustically-isolated cove side of the site on pile driving days more than on non-pile driving days. The effect of these responses may range from insignificant to permanent, long-term effects if feeding or reproduction is impaired.

Turnpenny et al. (1994) attempted to determine a level of underwater sound that would elicit behavioral responses in brown trout, bass, sole, and whiting. With brown trout an avoidance reaction occurred above 150 dB_{RMS}, and other reactions (e.g., a momentary startle), were noted at 170-175 dB_{RMS}. The report references Hastings' (1990) "safe limit" recommendation of 150 dB_{RMS} and concludes that the "safe limit" provides a reasonable margin below the lowest levels where fish injury was observed. In an associated literature review, Turnpenny and Nedwell (1994) also state that the Hastings' (1990) 150 dB_{RMS} limit did not appear overly stringent and that its application seemed justifiable. Additionally, observations by Feist et al. (1992) suggest that sound levels in this range may also disrupt normal migratory behavior of juvenile salmon.

Fewtrell (2003) held fish in cages in marine waters and exposed them to seismic airgun impulses. The study detected significant increases in behavioral response when sound pressure levels exceeded 158-163 dB_{RMS}. Responses included alarm, faster swimming, tighter grouping, and movement toward the lower portion of the cage. The study also evaluated physiological stress response by measuring plasma cortisol and glucose levels and found no statistically significant changes. Conversely, Santulli et al. (1999) found evidence of increased stress hormones after exposing caged European bass to seismic survey noise. Clearly, there is a substantial gap in scientific knowledge on this topic. Fewtrell (2003) presents some experimental data on behavioral responses of fishes to impulsive sounds above 158 dB_{RMS}. Given the large amount of uncertainty that lies not only in extrapolating from experimental data to the field, but also between sound sources (airguns vs. pile driving), and from one species to another, we believe it is appropriate to utilize the most conservative value for potential behavioral changes. As such, we expect that SPLs in excess of 150 dB_{RMS} may cause temporary behavioral changes in Chinook salmon, bocaccio, and bull trout. They are not expected to cause injury. We expect that SPLs above 150 dB_{RMS} could result in alteration of normal foraging and migrating behaviors.

Vibratory pile driving will be used to remove the timber piles and to install the steel piles. The elevated sound levels from a vibratory driver differ in waveform and rise times and are not currently associated with the same risk of physical injury as impact pile driving of steel piles. However, they are associated with potential behavioral changes. Whether these behavioral effects are adverse must be established based on a number of additional factors such as the duration and timing of exposure, species life histories, normal use of the area during exposure, and surrounding activities in the action area.

The steel piles will be driven primarily with a vibratory hammer. An impact hammer will be used for proofing to reach required elevations. Vibratory installation of steel piles produce sounds up to 180 dB_{peak}, 175 dB_{RMS}, and 175 dB_{SEL} (36 inch pile, WSDOT 2017); however, the sounds from vibratory installation differ from impact installation in intensity, frequency, and impulse energy (total energy content of the pressure wave) (Teachout, in litt. 2010, p. 15). Most of the sound generated by impact hammer pile driving steel piles is concentrated between 100

and 800 Hz, the frequencies thought to be most harmful to aquatic animals, while the sound energy from the vibratory pile driving steel piles is concentrated around 20 to 30 Hz (Teachout, in litt. 2010, p. 15). Additionally, during the strike from an impact hammer, the sound pressure rises much more rapidly than during the use of a vibratory hammer (Carlson et al. 2001, p. 23; Nedwell and Edwards 2002, p. 10). Depending on the location of the vibratory installation, SPLs may not exceed ambient sound levels. Vibratory installation of steel piles in a river in California resulted in SPLs that were not measurable above the background noise created by the current (Reyff 2006, p.2).

The sounds created by vibratory pile driving are different from impact installation and the responses of Chinook salmon, bocaccio, and bull trout are also expected to differ. We expect these fish can hear the sounds produced by vibratory pile driving, although the sound is at the low end and below the optimal hearing range of fishes, and that it could result in behavioral responses. The project involves vibratory and impact pile driving for up to 154 days.

The Services use 150 dB_{RMS} as guidance for potential behavioral effects to fish species. If SPLs exceed 150dB_{RMS} there is potential for disruption of normal migratory behavior of juvenile salmon and rockfish. The Services estimate with this project, SPLs will exceed 150 dB_{RMS} within a distance up to 5,574 meters (3.5 miles) from the construction site during vibratory pile driving (Figure **10**). Impact pile driving is not expected to result in significant behavioral responses as only 20 strikes per pile will be conducted on 4 piles per day (approximately 2 minutes of impact pile driving per day).

The project will be conducted along with several other projects in the action area using one or more vibratory pile drivers. This may result in significant behavioral changes to migrating or foraging Chinook salmon, bocaccio, and bull trout due to the constant insonification of the migratory corridor. Other projects in the action area using vibratory pile drivers include the Seawall Replacement Project (two pile drivers), Colman Dock (two and possibly three pile drivers), and Terminal 5 (three pile drivers) in the West Waterway of the Duwamish River. The cumulative increased SPLs from all these projects may result in significant behavioral changes to migrating or foraging juvenile and adult Chinook salmon, juvenile bocaccio, and juvenile, sub-adult, and adult bull trout. However, based on scientific information (as stated above) provided about vibratory pile driving on the intensity, frequency, and impulse energy of sound produced, and the high background sound levels within the action area, the Services consider the potential behavior changes from increased sound levels from vibratory pile driving to be insignificant. Although the behavioral effects from increased sound pressure levels from vibratory pile driving are insignificant, the effects are considered and addressed in the remainder of this analysis, particularly the Integration and Synthesis portion of the opinion.

Figure 10. Area of potential behavioral changes (5,574 meters, 3.5 miles) as a result of increased sound pressure levels from vibratory pile driving for Chinook salmon, bocaccio, and bull trout.

Injury and Death of Fish from Impact Pile Driving

Proofing the steel piles with an impact driver during installation will cause underwater sound pressure levels that are high enough to lead to injury or death (barotrauma). The Services use threshold criteria recommended by the inter-agency Fisheries Hydroacoustic Working Group and an interdisciplinary science panel (FHWG 2008; SAIC 2011; SAIC 2012).

A multi-agency working group of federal and state transportation and resource agencies, including underwater acoustics experts, fish biologists, and transportation specialists, has released agreed-upon for evaluating the potential for physical effects (i.e., injury) from underwater noise levels caused by pile driving. These criteria represent threshold values for

received levels, with the onset of injury expected if either: 1) dB_{peak} exceeds 206 dB; or 2) dB_{SEL}[9] wsaccumulated over all pile strikes, exceeds 187 dB for fishes two grams (0.07 ounces) or larger and 183 dB for fishes smaller than two grams (FHWG 2008). As stated above, 150 dB_{RMS} is a SPL the Services use for identifying the potential for behavioral changes to fish, but where direct injury or death would not be expected (USFWS 2012).

High underwater SPLs are known to cause negative physiological and neurological effects on a wide variety of vertebrate species (Hastings and Popper 2005; Turnpenny and Nedwell 1994; Yelverton et al. 1973; Yelverton and Richmond 1981), and are known to injure and/or kill fishes, as well as cause temporary stunning, and alterations in behavior (Hastings and Popper 2005; Popper 2003; Turnpenny and Nedwell 1994; Turnpenny et al. 1994). Over this continuum of effects, there is no easily identifiable point at which behavioral responses transition to physical effects, but the risk of injury appears related to the effect of rapid pressure changes, especially on gas-filled spaces in the bodies of exposed organisms (Turnpenny et al. 1994). With regard to fish kills, with few exceptions, they are generally reported only when dead or injured fish are observed at the surface and therefore the frequency and magnitude of such kills are likely underestimated.

Injuries associated with exposure to high SPLs are referred to as barotraumas, and include hemorrhage and rupture of internal organs, hemorrhaged eyes, and temporary stunning (Hastings and Popper 2005; Turnpenny and Nedwell 1994; Yelverton et al. 1973; Yelverton et al. 1975; Yelverton and Richmond 1981). Death as a result of barotrauma can be instantaneous, occurring within minutes after exposure, or can occur several days later (Abbott et al. 2002), or injuries may be sublethal.

Necropsy results from Sacramento blackfish (*Othodon microlepidotus*) exposed to high SPLs showed fish with extensive internal bleeding and a ruptured heart chamber were still capable of swimming for several hours before death (Abbott et al. 2002). Sub-lethal injuries can reduce osmoregulatory efficiency and increase energy expenditure (Gaspin et al. 1976, Govoni et al. 2008), and can effect equilibrium and interfere with the ability to carry out essential life functions such as feeding and predator avoidance (Gaspin 1975; Turnpenny et al. 1994; Hastings et al. 1996; Popper 2003).

Multiple factors influence the effects of impact pile driving: 1) type and intensity of sounds produced depends the type of hammer, the type of substrate, and the depth of water (eg, firmer substrates require more energy for driving and produce more intense sound pressures); and 2, key variables that determine the degree to which an animal is affected include size, anatomical variation, and location in the water column (eg, gas-filled structures such as swimbladder, bowel, sinuses or lungs, are particularly susceptible to the effects of underwater sound (Gisiner et al. 1998). Sound energy from an underwater source readily enters the bodies of exposed organisms because the acoustic impedance of animal tissue nearly matches that of water (Hastings 2002). As a sound pressure wave passes through a fish, the swim bladder is rapidly compressed due to the high pressure and then rapidly expanded by the underpressure. At the high SPLs associated with pile driving, the swim bladder may repeatedly expand and contract. This essentially hammers adjacent tissue and organs that are bound in place near the swim bladder (Gaspin

[9] Throughout this document, the reference value for dB SEL is 1 μPa^2-sec.

1975). Exposure to this type of pneumatic pounding (resulting from pile driving) can cause rupture of capillaries in the internal organs, as observed in fishes with blood in the abdominal cavity, and maceration of kidney tissues (Abbott et al. 2002; Stadler, pers. comm. 2002).

Yelverton and Richmond (1981) and Yelverton et al. (1973) exposed a variety of fish species, various birds, and terrestrial mammals to underwater explosions. Common to all the species were injuries to air- and gas-filled organs, as well as eardrums. These studies identified injury thresholds in relation to the size of the charge, the distance at which the charge was detonated, and the mass of the exposed animal. Yelverton et al. (1973) and Yelverton and Richmond (1981) found that the greater the fish's mass, the greater impulse level needed to cause an injury. Conversely, a fish with smaller mass would sustain injury from a smaller impulse.

At Bremerton, Washington, approximately 100 surfperch (*Cymatogaster aggregata*, *Brachyistius frenatus* and *Embiotoca lateralis*) were killed during impact driving of 30-inch diameter steel pilings (Stadler, Pers Comm, 2002). The size of these fish ranged from 70 mm to 175 mm fork length. Dissections revealed that the swim bladders of the smallest of the fishes (80 mm fork length) were completely destroyed, while those of the largest individual (170 mm fork length) were nearly intact. Damage to the swim bladder of *C. aggregata* was more severe than to similar-sized *B. frenatus*. These results are suggestive of size and species-specific differences and are consistent with those of Yelverton et al. (1975) who found size and/or species differences in injury from underwater explosions.

Examination of the current literature indicates that physical damage to non-auditory tissue is best evaluated through the use of an energy index that is indicative of mechanical effects to the tissue, and that is independent of whether the pressure is positive or negative. This can be estimated using cumulative SEL; however, the most relevant data (Yelverton et al. 1975; Wiley et al. 1981; Stuhmiller et al. 1996, Bailey et al. 1996) are not reported in cumulative SEL, and the raw data necessary to calculate SEL is not contained in these reports.

Using data from an unpublished study of the effects of underwater explosions on fishes, Hastings (Hastings pers. comm. 2007) determined that an SEL as low as 183 dB (re: 1 μPa_2-sec) was sufficient to injure the nonauditory tissues of juvenile spot (*Leiostomus xanthurus)* and pinfish (*Lagodon rhomboides*) with an estimated mass of 0.5 grams. While previous studies (Yelverton et al. 1975; Stuhmiller et al. 1996) demonstrated a log-log relationship between the mass of a fish and the cumulative SEL from an impulsive sound required to induce injury, data on the cumulative SEL required to injure the non-auditory tissues of larger fishes are not available, and the slope of this relationship cannot be positively ascertained at this time.

Popper et al. (2005) and Song et al. (2008) investigated the effects of exposing three species of fish to airgun shots at a mean received level of 205-209 dB_{peak} and an approximate received mean of 176-180 dB SEL. The inner ears of these fishes were examined and no physical damage to the sensory cells was found (Song et al. 2008). The authors note that the onset and degree of temporary threshold shift (TTS) varied among species, with broad whitefish (*Coregonus nasus*) showing no effect after cumulative SEL exposures up to 187 dB. Northern pike (*Esox lucius*) and lake chub (*Couesius plumbeus*) (a hearing specialist) showed TTS after exposure to cumulative SELs as low as 185 dB and 184 dB, respectively (Popper et al. 2005). This work indicates that

substantial differences exist in the effects of high SPLs on the hearing thresholds of different species; fish with poorer hearing (the pike) showed little hearing loss, while the fish with the best hearing (the lake chub) had the most loss (Popper et al. 2005). The authors also note that the sounds of airguns are characterized by relatively rapid onset, broad frequency ranges, and high peak levels, making them more similar to sounds from pile driving and explosions than to ship noise or sonar (Popper et al. 2005).

The project involves the installation of 189 steel piles, 30-inch diameter, over two construction seasons. In the first season, 11 days of pile driving will occur, starting in November, 2017. In the second season, 11 days of pile driving will occur in September and October, 2018, and 11 days in November, 2018, through February, 2019. Four piles will be installed per day. The piles will be first installed with a vibratory driver and then proofed with an impact pile driver. Each pile will require 20 strikes with an impact hammer. A bubble curtain will be used during impact pile driving with hydroacoustic monitoring to verify an 8 dB reduction in sound levels. The area of potential injury associated with impact installation of the steel piles is a 48 meter (157 foot) radius around each pile for fish greater than 2 grams (
Figure 11). Thus, the Services expect that all Chinook salmon, bocaccio, and bull trout within 48 meters (157 feet) of impact pile driving of steel that are exposed to elevated SPLs will be injured or killed. The City will be installing a sediment curtain around the project area. The sediment curtain will be installed within 200 feet along the south side of Pier 62 to allow barge use. The installation of the sediment curtain will exclude Chinook salmon, bocaccio, and bull trout from the project area and minimize exposure to increased sound pressure levels.

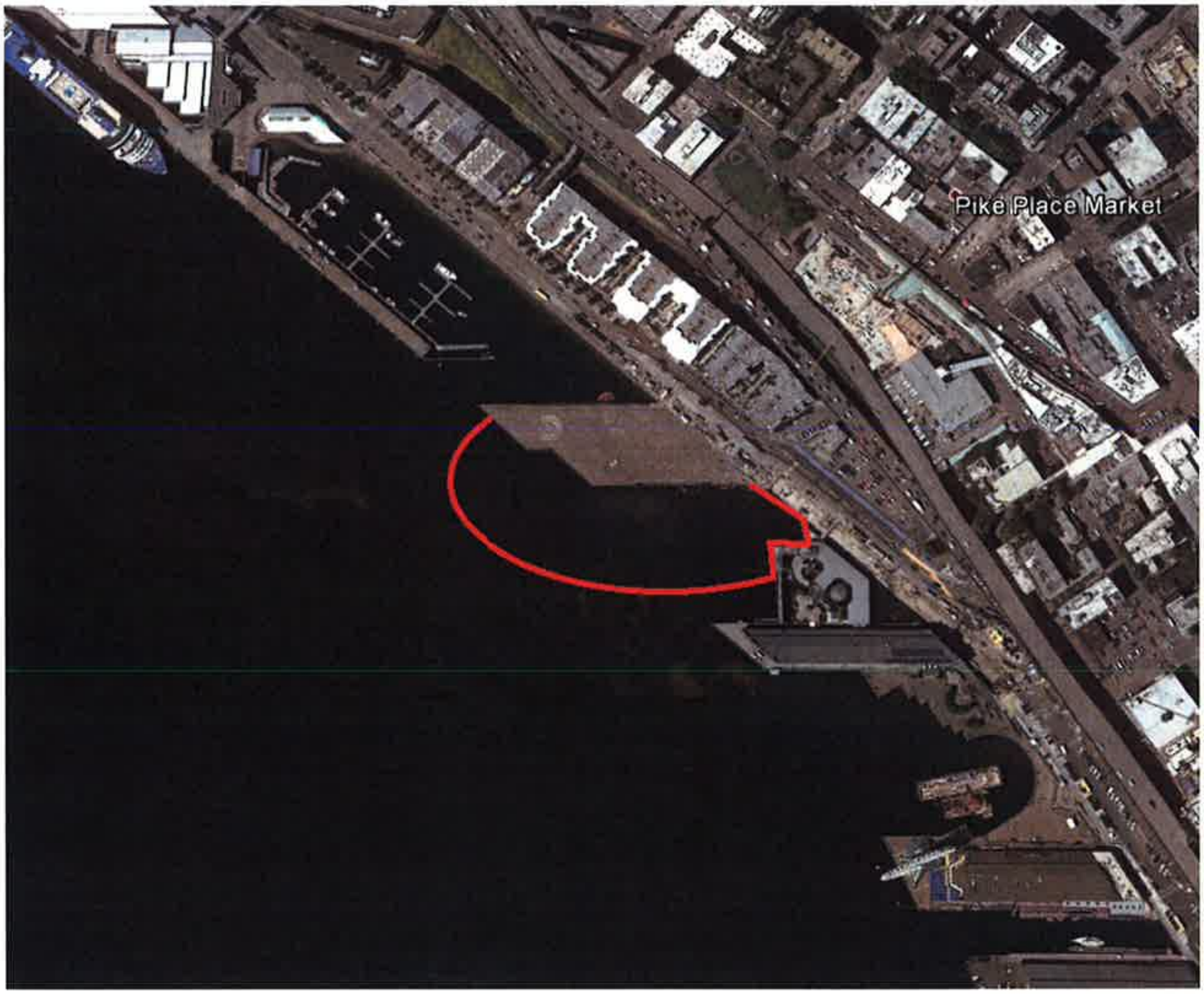

Figure 11. Area of potential injury (48 meters, 157 feet) around each pile. Area shown is the area of injury around the project site as a result of impact pile driving and the use of a bubble curtain.

Estimated Injury or Death of Chinook from Impact Driving. Because the juvenile Chinook salmon in the project area in September and October when impact pile driving will occur will all be heavier than 2 grams (Toft, in litt. 2013b), all Chinook salmon within a 48 meter (157 foot) radius of impact pile driving will be injured or die. Since the area of potential injury around each pile extends both between the existing piers and out beyond Pier 62/63, the Services assume that the number of Chinook salmon in the area between and out beyond the piers is equal to the number of fish found along the seawall plus those that are found in deeper water (surface trawl data). Along the seawall and between the piers, the average number of Chinook salmon was 1.8 fish/520 m^2 (5,597 ft^2) in September and 0.6 fish/520 m^2 (5,597 ft^2) in October (UW unpublished data). Beyond the piers in deeper water, juvenile Chinook salmon were found at a mean density of approximately 2.5 Chinook salmon/hectare in September and 0.5 Chinook salmon/hectare in October. Therefore, the number of Chinook salmon between and out beyond the piers is equal to 37 Chinook salmon/hectare in September (1.8 Chinook salmon /520 m^2 = 34.6 Chinook salmon

/hectare; 34.6 Chinook salmon /hectare plus 2.5 Chinook salmon /hectare = 37 Chinook salmon /hectare) and 12 Chinook salmon/hectare in October (0.6 Chinook salmon /520 m^2 = 11.5 Chinook salmon /hectare; 11.5 Chinook salmon /hectare plus 0.5 Chinook salmon /hectare = 12 Chinook salmon /hectare).

Impact pile driving will occur for 11 days during each of the following time frames: the first construction season from November, 2017 through February, 2018; second construction in September and October, 2018, and between November, 2018, and February, 2019. Because Chinook salmon are not found along the seawall and piers between November and February, increased SPLs from impact pile driving will not result in injury or mortality of Chinook salmon during this time. Because impact pile driving will occur for 11 days in September and October, 2018, when juvenile Chinook salmon will be present in the action area, the Services conducted their analysis that all 11 days of impact pile driving will occur in September when more juvenile Chinook salmon are found in the action area. Based on that analysis, the Services estimate that up to 19 juvenile Chinook salmon/day will be injured or die due to impact pile driving activities in September and October. The 19 juvenile Chinook salmon/day is based on a half hectare being the size of a 48 meter radius from the pile installation and using the assumption that a quarter of the sound will be under the pier.

Injury and death among juvenile Chinook salmon due to impact pile driving will negatively affect the viability of the population only if their abundance is diminished to the point that the number of returning spawning pairs is reduced. Marine survival of juvenile Chinook salmon is estimated to be between 0.1 to 2.0 percent (Duffy and Beauchamp 2011). This is based off of hatchery released Chinook salmon. Factors that influenced marine survival of hatchery fish included release date, size at release, and average mass in July and September. The 19 juvenile Chinook salmon/day that may be injured or die from impact pile driving in September and October, 2018, equals 209 juveniles (19 * 11 days of impact pile driving). The estimated adult equivalence is 0.21 to four adults (0.1 to 2.0 percent). The loss of these adults is less than 0.1 percent of the average returning escapement numbers over the last 5 years at both the Green/Duwamish River and the Skykomish River (WDFW 2017).

Estimated Injury or Death of Bocaccio from Impact Pile Driving. Because little information is available on densities of rockfish in and around the piers, the Services used the same numbers and calculations from the turbidity and suspended solids analysis for impacts of pile driving to bocaccio. The Services also assume that by September and October, bocaccio will all be larger than 2 grams. From the analysis above under turbidity and suspended solids, the density estimates for bocaccio in both September and October is 0.00002 larvae/1,000 m^3. During impact pile driving in September and October, 2018, all rockfish within 48 meters (fish greater than 2 grams) radius of impact pile driving will be injured or die.

The volume of water within the 48 meter radius of impact pile driving, with an average depth of 15 meters at the end of the piers (SDOT 2012e), is approximately 104,000 m^3. Therefore, the number of bocaccio affected by impact pile driving will be 0.02 in both September and October. Because these numbers are very small, the Services estimate that one bocaccio will be injured or die as a result of increased sound pressure levels during impact pile driving in September and October, 2018.

Estimated Injury or Death of Bull Trout from Impact Pile Driving. Bull trout use the marine nearshore for migration and foraging. Bull trout are found along the nearshore in the vicinity of prey species which include juvenile salmonids. One bull trout was observed on the habitat bench along the Olympic Sculpture Park in 2009 and several radio-tagged bull trout moved between the Snohomish River and the Duwamish River, indicating that they may be present in low numbers any time of the year. Because impact pile driving will occur for approximately 33 days during the two years of in-water project construction, the Services estimate that one bull trout will be injured or die within the 48 meter radius around pile installation as a result of exposure to increased sound pressure levels during impact pile driving.

Effects of Elevated Underwater SPLs on Marine Mammals

Hearing is the most important sensory modality for marine mammals underwater, and exposure to anthropogenic sound can have deleterious effects. To appropriately assess the potential effects of exposure to sound, it is necessary to understand the frequency ranges marine mammals are able to hear. Studies have found that not all marine mammal species have equal hearing capabilities (*e.g.*, Richardson *et al.* 1995; Wartzok and Ketten 1999; Au and Hastings 2008). Generalized hearing for low-frequency cetaceans (humpback whales) is estimated to occur between approximately 7 hertz (Hz) and 35 kilohertz (kHz), with best hearing estimated to be from 100 Hz to 8 kHz. Generalized hearing for mid-frequency cetaceans (killer whales) is estimated to occur between approximately 150 Hz and 160 kHz, with best hearing from 10 to less than 100 kHz.

Potential Effects of Specified Activities on Marine Mammals and their Habitat

Exposure to high intensity sound for a sufficient duration may result in auditory effects such as a noise-induced threshold shift (TS), which is an increase in the auditory threshold after exposure to noise (Finneran *et al.* 2005). Factors that influence the amount of TS include the amplitude, duration, frequency content, temporal pattern, and energy distribution of noise exposure. The magnitude of hearing TS normally decreases over time following cessation of the noise exposure. The amount of TS just after exposure is the initial TS. If the TS eventually returns to zero (*i.e.*, the threshold returns to the pre-exposure value), it is a temporary threshold shift (TTS)(Southall *et al.* 2007).

Threshold Shift (noise-induced loss of hearing)

When animals exhibit reduced hearing sensitivity (*i.e.*, sounds must be louder for an animal to detect them) following exposure to an intense sound or sound for long duration, it is referred to as TS. An animal can experience TTS or permanent threshold shift (PTS). TTS can last from minutes or hours to days (*i.e.*, there is complete recovery), can occur in specific frequency ranges (*i.e.*, an animal might only have a temporary loss of hearing sensitivity between the frequencies of 1 and 10 kHz), and can be of varying amounts (for example, an animal's hearing sensitivity might be reduced initially by only 6 dB or reduced by 30 dB). PTS is permanent, but some recovery is possible. PTS can also occur in a specific frequency range and amount as mentioned above for TTS.

For marine mammals, published data are limited to the captive bottlenose dolphin, beluga, harbor porpoise, and Yangtze finless porpoise (Finneran *et al.*, 2000, 2002, 2003, 2005, 2007, 2010a, 2010b; Finneran and Schlundt, 2010; Lucke *et al.*, 2009; Mooney *et al.*, 2009a, 2009b; Popov *et al.*, 2011a, 2011b; Kastelein *et al.*, 2012a; Schlundt *et al.*, 2000; Nachtigall *et al.*, 2003, 2004).

Lucke *et al.* (2009) found a TS of a harbor porpoise after exposing it to airgun noise with a received SPL at 200.2 dB (peak–to-peak) re: 1 μPa, which corresponds to a sound exposure level (SEL) of 164.5 dB re: 1 μPa^2 s after integrating exposure. NMFS currently uses the rms of received SPL at 180 dB re: 1 μPa as the threshold above which PTS could occur for cetaceans. Because the airgun noise is a broadband impulse, one cannot directly determine the equivalent of rms SPL from the reported peak-to-peak SPLs. However, applying a conservative conversion factor of 16 dB for broadband signals from seismic surveys (McCauley *et al.* 2000) to correct for the difference between peak-to-peak levels reported in Lucke *et al.* (2009) and rms SPLs, the rms SPL for TTS will be approximately 184 dB re: 1 μPa, and the received levels associated with PTS (Level A harassment) will be higher. However, NMFS recognizes that TTS of harbor porpoises is lower than other cetacean species empirically tested (Finneran and Schlundt 2010; Finneran *et al.* 2002; Kastelein and Jennings 2012).

Marine mammal hearing plays a critical role in communication with conspecifics, and interpretation of environmental cues for purposes such as predator avoidance and prey capture. Depending on the degree (elevation of threshold in dB), duration (*i.e.*, recovery time), and frequency range of TTS, and the context in which it is experienced, TTS can have effects on marine mammals ranging from discountable to serious (similar to those discussed in auditory masking, below). For example, a marine mammal may be able to readily compensate for a brief, relatively small amount of TTS in a non-critical frequency range that occurs during a time where ambient noise is lower and there are not as many competing sounds present. Alternatively, a larger amount and longer duration of TTS sustained during time when communication is critical for successful mother/calf interactions could have more serious impacts. Also, depending on the degree and frequency range, the effects of PTS on an animal could range in severity, although it is considered generally more serious because it is a permanent condition. Reduced hearing sensitivity as a simple function of aging has been observed in marine mammals, as well as humans and other taxa (Southall *et al.* 2007), so one can infer that strategies exist for coping with this condition to some degree, though likely not without cost.

Masking

Chronic exposure to excessive, though not high-intensity, noise could cause masking at particular frequencies for marine mammals that utilize sound for vital biological functions (Clark *et al.* 2009). Acoustic masking is when other noises such as from human sources interfere with animal detection of acoustic signals such as communication calls, echolocation sounds, and environmental sounds important to marine mammals. Therefore, under certain circumstances, marine mammals whose acoustical sensors or environment are being severely masked could also be impaired from maximizing their performance fitness in survival and reproduction.

Masking occurs at the frequency band that the animals utilize. Since noise generated from vibratory pile driving activity is mostly concentrated at low frequency ranges, it may have less

effect on high frequency echolocation sounds by odontocetes (killer whales). However, lower frequency man-made noises are more likely to affect detection of communication calls and other potentially important natural sounds such as surf and prey noise. It may also affect communication signals when they occur near the noise band and thus reduce the communication space of animals (*e.g.*, Clark *et al.* 2009) and cause increased stress levels (*e.g.*, Foote *et al.* 2004; Holt *et al.* 2009).

Unlike TS, masking, which can occur over large temporal and spatial scales, can potentially affect the species at population, community, or even ecosystem levels, as well as individual levels. Masking affects both senders and receivers of the signals and could have long-term chronic effects on marine mammal species and populations. Science suggests that low frequency ambient sound levels have increased by as much as 20 dB (more than three times in terms of sound pressure level) in the world's ocean from pre-industrial periods, and most of these increases are from distant shipping (Hildebrand 2009). For the proposed action, noises from vibratory pile driving and pile removal contribute to the elevated ambient noise levels in the project area, thus increasing potential for or severity of masking. Baseline ambient noise levels in the vicinity of project area are high due to ongoing shipping, construction and other activities in the Puget Sound.

Behavioral disturbance

Marine mammals' exposure to certain sounds could lead to behavioral disturbance (Richardson *et al.,* 1995), such as: changing durations of surfacing and dives, number of blows per surfacing, or moving direction and/or speed; reduced/increased vocal activities; changing/cessation of certain behavioral activities (such as socializing or feeding); visible startle response or aggressive behavior (such as tail/fluke slapping or jaw clapping); and/or avoidance of areas where noise sources are located.

The onset of behavioral disturbance from anthropogenic noise depends on both external factors (characteristics of noise sources and their paths) and the receiving animals (hearing, motivation, experience, demography) and is difficult to predict (Southall *et al.,* 2007). Currently NMFS uses a received level of 160 dB_{RMS} re 1 μPa to predict the onset of behavioral harassment from impulse noises (such as impact pile driving), and 120 dB_{RMS} re 1 μPa for continuous noises (such as vibratory pile driving). For the proposed action, both of these noise levels are considered for effects analysis because the City plans to use both impact and vibratory pile driving, as well as vibratory pile removal.

The biological significance of many of these behavioral disturbances is difficult to predict, especially if the detected disturbances appear minor. The consequences of behavioral modification could be biologically significant if the change affects growth, survival, and/or reproduction, which depends on the severity, duration, and context of the effects.

<u>Estimates of Marine Mammal Exposure to Elevated Sound during Construction.</u>

The NMFS developed comprehensive guidance on sound levels likely to cause injury and behavioral disruption in the context of the Marine Mammal Protection Act. NMFS uses

conservative thresholds of sound pressure levels from broad band sounds that cause behavioral disturbance (160 dB_{RMS} for impulse sound and 120 dB_{RMS} for continuous sound) and injury (180 dB_{RMS} for whales) (January 11, 2005, 70 FR 1871).

Based on these conservative thresholds, the proposed pile driving activities will produce sound pressure levels that could disturb or injure marine mammals. To ensure injury will not occur, the applicant has proposed a marine mammal monitoring plan for this project during all pile driving (Appendix B). Under the plan, the applicant will monitor for marine mammals within the project area as defined in Table 9 and issue a stop-work order if mammals are detected in the identified areas.

Table 9. Summary Table of Exclusion Zone Thresholds and Level B Harassment Zones.

Action Type	Level A Harassment[1] Distance to 160 dB_{RMS} Impact Disturbance Threshold from Measured Sound (meters)	Level B Harassment[1] Distance to 124 dB_{RMS} Vibratory Disturbance Threshold (Background) from Measured Sound (meters)
Impact Driving – 30-inch Steel Pipe Piles	1,201	N/A
Vibratory Driving – 30-inch Steel Pipe Piles	N/A	54,117
Vibratory Removal – 14-inch Timber Piles	N/A	1,865

1 Level A 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 B harassment is define as any act of pursuit, torment, or annoyance which 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.

As there are not density estimates for marine mammal populations in Puget Sound, the Services use anecdotal reports, incidental observations, and data from previous consultations around Puget Sound to determine the number of marine mammals that may be impacted by the project.

Estimate of Southern Resident Killer Whales Exposure to Elevated Sound. Based on past sightings of killer whales within the action area, the Services estimate that 24 killer whales will experience significant disruption in normal behaviors (Level B harassment outside the stop-work order zone, see Table 9), such as increased stress leading to reduced ability to perform vital functions such as migration, breathing, nursing, breeding, feeding, or sheltering, as a result of increased sound pressure levels during pile driving activities. This disruption in normal behaviors will occur during project construction between September 1, 2017, and February 28, 2018.

Most of the sound pressure produced by a tugboat towing a loaded barge is expected to be below the level of peak hearing sensitivity for killer whales. When the tugboat is in motion, sound pressure levels will be transient and are therefore expected to be below background levels a short

distance from any one location. Thus, tugboat/barge sound is unlikely to mask acoustic signals of biological significance to killer whales.

Estimate of Humpback Whales Exposure to Elevated Sound. Based on the average groups size and observed occurrence of humpback whales within the action area, the Services estimate that five humpback whales will experience significant disruption in normal behaviors (Level B harassment outside the stop-work order zone, see Table 9), such as increased stress leading to reduced ability to perform vital functions such as migration, breathing, nursing, breeding, feeding, or sheltering as a result of increased sound pressure levels during pile driving activities. This disruption in normal behaviors will occur during project construction construction between September 1, 2017, and February 28, 2018.

2.5.1 Summary of Effects to Chinook Salmon, Bocaccio, and Bull Trout

The proposed project will result in a variety of effects to Chinook salmon, bocaccio, and bull trout. Minimal effects will result from the shading from the overwater structure and potential behavioral changes from vibratory pile driving, Grating installed along the nearshore minimizes shading effects and improves the migratory corridor for Chinook salmon, bocaccio, and bull trout. In-water construction including the isolation of the work area and the removal and installation of piles will result in behavioral changes, injury, and mortality of Chinook salmon, bocaccio, and bull trout through increased contaminants, turbidity, suspended sediments, and sound pressure levels. Chinook salmon and bocaccio that are within 15 meters (50 feet) will be exposed to elevated contaminants, turbidity, and suspended sediments. The Services expect 312 juvenile Chinook salmon and 2 larval bocaccio will be injured, die, or have significant disruption in normal behavior as a result of increased contaminants, turbidity, and suspended sediments or from installation of the sediment curtain over the two years of construction.

Impact pile driving will result in injury or mortality of all Chinook salmon, bocaccio, and bull trout within 48 meters (157 feet) of each pile. Impact pile driving will occur for 11 days during each of the following time frames: the first construction season from November, 2017 through February, 2018; second construction in September and October, 2018, and between November, 2018, and February, 2019. The Services expect 209 juvenile Chinook salmon, one bocaccio, and one bull trout will be injured or die as a result of exposure to increased sound pressure levels during impact pile driving.

2.5.2 Summary of Effects to Killer Whales and Humpback Whales

Vibratory and impact pile driving will result in increased sound pressure levels that causes auditory, masking, and behaviroal distrubance effects to killer and humpback whales. Based on sightings of whales within the action area, 24 killer whales and five humpback whales will experience significant disruption in normal behaviors as a result of increased sound pressure levels from vibratory and impact pile driving.

2.5.3 Effects on the Designated Critical Habitat of Listed Species

The proposed action is likely to adversely affect the designated critical habitat of Chinook salmon, bocaccio, and SR killer whales.

Puget Sound Chinook Salmon Critical Habitat

The NMFS designated critical habitat for Chinook salmon on September 2, 2005 (70 FR 52630). One of the six PCEs of Chinook salmon critical habitat is in the action area:

- Chinook Salmon PCE 5: Nearshore marine areas free of obstruction with water quality and quantity conditions and forage, including aquatic invertebrates and fish, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.

Effects on the Essential Elements of the Nearshore Marine PCE. The project will cause temporary and permanent effects to habitat features of the nearshore marine area for Chinook salmon.

Obstructions and Natural Cover – The project replaces the existing overwater structure with a smaller, similar structure that maintains the degraded condition of the habitat by continuing to preclude and/or degrade natural shoreline/riparian processes provided by natural cover. Overall, the project reduces overwater structure by 800 square feet and increases light penetration under the pier by replacing 4,583 square feet of solid structure with grating. Grating will be installed along the new seawall habitat bench that will improve the migratory corridor through the area and minimize underwater light contrasts. The project will not affect the conservation role of this habitat feature of this PCE.

Water Quality/Turbidity and Suspended Solids – Water quality is an essential element of the nearshore marine PCE in the action area, and will be directly affected by the proposed action. Removal of the timber piles and installation of the steel piles will each increase turbidity and suspended solids within 50 feet of these activities. Pile removal and installation will occur from August through October when Chinook salmon will be within the action area. Increased turbidity and suspended sediments from the removal and installation of piles, when Chinook salmon are present during construction from August through October will impair the nearshore marine environment and therefore will adversely effect the conservation role of this habitat feature of this PCE.

Forage and Prey - Project construction will result in a short-term temporary decrease in Chinook salmon prey. Pile removal and installation will result in macroinvertebrates being displaced and killed as well as their habitat altered or destroyed. Pile removal and installation will also result in increased turbidity and suspended sediments that will result in the loss of prey species. However, macroinvertebrates will quickly recolonize the disrupted areas from the surrounding area. The temporary reduction in forage and prey will not impair the ability of the action area to support the growth and maturation of Chinook salmon in the action area and will not affect the conservation role of this habitat feature of this PCE.

Relevance of Action Area Effects to Designated Critical Habitat

Designated Chinook salmon critical habitat within Elliott Bay, in which the action area occurs, is rated as having medium conservation value for Chinook salmon; the importance of this location

is based on the role it plays for supporting nearshore growth and maturation for Chinook salmon utilizing the action area. The episodic and intermittent construction related impacts (to the nearshore marine PCE) in designated critical habitat in Elliott Bay occurs primarily from pile removal and installation activities. These ephemeral effects will not diminish the PCE in a way that causes a reduction in the conservation role of the critical habitat. The temporary effects of increased turbidity and suspended solids is insufficient to alter the ability of the action area to support the growth and maturation of Chinook salmon.

Bocaccio Critical Habitat

The NMFS designated critical habitat for bocaccio on November 13, 2014 (79 FR 68041). Both PCEs for bocaccio critical habitat are in the action area:

- Deepwater Critical Habitat: Adult bocaccio. Sites deeper than 98 feet (30 m) that possess (or are adjacent to) areas of complex bathymetry. These features are essential to conservation because they support growth, survival, reproduction, and feeding opportunities by providing the structure to avoid predation, seek food, and persist for decades. Deepwater attributes include: 1) quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities; 2) water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities; and 3) structure and rugosity to support feeding opportunities and predator avoidance.

- Nearshore Critical Habitat: Juvenile bocaccio: Juvenile settlement sites located in the nearshore with substrates such as sand, rock, and/or cobble compositions that also support kelp. These features are essential for conservation because they enable forage opportunities and refuge from predators, and enable behavioral and physiological changes needed for juveniles to occupy deeper adult habitats. Nearshore attributes include: 1) quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities; and 2) water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities.

Construction effects will not affect deepwater attributes for adult bocaccio. Increased sound pressure levels from pile driving activities to remove the timber piles and install steel piles will not result in any temporary and permanent effects to the deepwater attributes. Therefore, no further analysis is discussed.

The project will cause temporary and permanent effects to the nearshore attributes for juvenile bocaccio.

Quantity, quality, and availability of prey: Project construction will result in the short-term temporary decrease in bocaccio prey. Pile removal and installation will result in macroinvertebrates being displaced and killed as well as their habitat altered or destroyed. Pile removal and installation will also result in increased turbidity and suspended sediments that will result in the loss of prey species. However, macroinvertebrates will quickly recolonize the

disrupted areas from the surrounding area. The temporary reduction in forage and prey will not impair the ability of the action area to support the growth, survival, reproduction, and feeding of juvenile bocaccio in the action area and will not affect the conservation role of this habitat feature of this PCE

Water Quality/Turbidity and Suspended Solids – Removal of the timber piles and installation of the steel piles will each increase turbidity and suspended solids that will temporarily degrade water quality conditions within the project area. Pile removal and installation will occur from August through February the first construction season and September through February the second year when the number of bocaccio within the action area is low. Increased turbidity and suspended sediments from the removal and installation of piles, when juvenile bocaccio may be present during construction from August through October will impair the nearshore marine environment and therefore will adversely effect the conservation role of this habitat feature of this PCE.

Relevance of Action Area Effects to Designated Critical Habitat

Designated bocaccio critical habitat within Elliott Bay is rated as having medium conservation value for bocaccio; the importance of this location is based on the role it plays for supporting individual growth, survival, reproduction, and feeding opportunities for bocaccio utilizing the action area. The episodic and intermittent construction related impacts (to the nearshore marine PCE) in designated critical habitat in Elliott Bay occurs primarily from pile removal and installation activities. These ephemeral effects will not diminish the PCE in a way that causes a reduction in the conservation role of the critical habitat. The temporary effects of increased turbidity and suspended solids is insufficient to alter the ability of the action area to support the individual growth, survival, reproduction, and feeding opportunities of bocaccio.

Southern Resident Killer Whale Critical Habitat

Critical habitat for SR killer whales was designated in three specific areas: 1) summer core area in Haro Strait and waters around the San Juan Islands; 2) Puget Sound; and 3) the Strait of Juan de Fuca on November 29, 2006 (71 FR 69054). Critical habitat includes approximately 2,560 square miles of Puget Sound, excluding areas with water less than 20 feet deep relative to extreme high water. The PCEs for SR killer whale 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) Passage conditions to allow for migration, resting, and foraging.

The project will cause temporary effects to the PCES listed below:

Water Quality – The project will temporarily degraded water quality due to increased turbidity and suspended solids during pile removal and installation. However, the effects will be

intermittent and limited in physical extent and duration. The temporary degradation in water quality will not impair the ability of the action area to support the growth and development of killer whales in the action area and will not affect the conservation role of this habitat feature of this PCE.

Prey Quantity, Quality and Availability – The proposed project will not result in any loss or injury of adult salmonids. Vibratory and impact pile driving may result in a behavioral disruption to adult salmonids within 2,929 meters (1.8 miles) of the project site. However, elevated sound levels are not anticipated to affect the behavior of adult salmonids to the degree that injury will occur. The project construction is expected to result in injury or mortality of 512 Chinook salmon due to pile driving, contaminants, turbidity, and/or suspended solids. Marine survival of juvenile Chinook salmon is estimated to be between 0.1 to 2.0 percent (Duffy and Beauchamp 2011). This is based off of hatchery released Chinook salmon. Factors that influenced marine survival of hatchery fish included release date, size at release, and average mass in July and September. The estimated adult equivalence for the 512 juvenile Chinook salmon/day that may be injured or die from impact pile driving is 0.5 to 10 adults (0.1 to 2.0 percent). Injury and death among juvenile Chinook salmon due to impact pile driving will negatively affect killer whale prey quantity, only if their abundance is diminished to the point that the number of returning adults is significantly reduced. The loss of up to 10 adult Chinook salmon will significantly reduce killer whale prey abundance. The proposed project will not affect the conservation role of this habitat feature of this PCE.

Passage – Killer whale migration will be impacted due to project construction. Vibratory pile driving will occur to remove and install the piles. Vibratory pile driving results in behavioral effects that may alter killer whale migration. The increased sound pressure levels includes the marine waters of Elliott Bay and Puget Sound from Manchester, just southwest of Bainbridge Island, to Ferncliff on Banbridge Island. Increased sound pressure levels from the removal and installation of piles will impair the migratory corridor, potentially blocking or redirecting killer whale migration through the action area and within Puget Sound and therefore, will adversely effect the conservation role of this habitat feature of this PCE.

2.6 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 CFR 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.

Some continuing non-federal activities, such as continued increases in impervious surfaces from commercial and industrial growth in the action area, are reasonably certain to contribute to climate effects (increased air and water temperatures) within the action area. However, it is difficult if not impossible to distinguish between the action area's future environmental conditions caused by global climate change that are properly part of the environmental baseline *vs.* cumulative effects. Therefore, all relevant future climate-related environmental conditions in the action area are described in the environmental baseline (Section 2.4).

Table 10 contains a list of non-federal projects that are reasonably certain to occur within the action area, along with a summary of the anticipated effects of those projects. Many of these projects are in the uplands, adjacent to the marine waters of Elliott Bay. However, no work will occur below the MLLW line and therefore these projects will not have a federal nexus. The action area is in a highly urbanized setting that is almost completely developed. Development is expected to spread to the surrounding areas which are not as intensively developed. The increase in development results in increased noise from traffic, and stormwater and contaminants entering Elliott Bay. Some developments, when sufficient area exists, improve stormwater runoff by constructing green stormwater infrastructure conveyance and flow control facilities, such as bioswales, bioretention cells, cascading planters, and other low impact development such as green roofs and permeable pavement sidewalks, where these features did not previously exist. Other projects use basic water treatment for stormwater runoff. While these projects improve water quality from the project sites, the areas using low impact development will likely continue to be a very small proportion of the overall developed area which drains to Elliott Bay.

Some of the projects identified in Table 10 will have no effect on listed species because there is no suitable habitat for those species within the vicinity of the projects. Other projects that create additional PGIS may generate more pollutants that will be discharged to Elliott Bay. However, over the long term, these future projects would likely improve water quality in Elliott Bay, due to implementation of the following legally-required measures:

- Retrofit currently untreated PGIS with, at a minimum, basic water quality treatment BMPs in stormwater sub-basins.

- Reduction of peak flows and the frequency of combined sewer overflows through the application of detention facilities to control runoff from combined sewer sub-basins.

- Conversion of PGIS to non-PGIS or pervious surfaces.

Some future actions will cause temporary adverse effects on water quality. For example, it is likely that construction effects on surface water will occasionally result during staging, material transport, earthwork, stockpiling, storm drainage and/or combined sewer utility work, and dewatering affiliated with shoreline development near but above the ordinary high water mark. Construction-related pollutants can increase turbidity and affect other water quality parameters, such as the amount of available oxygen in the water. In addition, pH can be altered if runoff comes in contact with curing concrete, which could result in effects on aquatic species. Implementation of BMPs will minimize or prevent temporary effects.

Future State, tribal, local, and private actions will have both beneficial effects and adverse effects to Chinook salmon, bocaccio, bull trout, killer whales, humpback whales and their designated critical habitat. However, the Services expect that the cumulative effect of these actions over time will be overall, beneficial. At the scale of the action area, we expect that future actions will improve water quality through required treatment and improve water quality attribute function of designated critical habitat and address important limiting factors on normal Chinook salmon, bocaccio, bull trout, killer whale, and humpback whale reproduction, growth, and survival.

Table 10. Projects that are reasonably certain to occur along the Seattle Waterfront.

Project	Potential Cumulative Effect
1. *Waterfront Seattle Program* Development of the Seattle Waterfront from the Olympic Sculpture Park to Pioneer Square. The project involves rebuilding the waterfront with parks, paths, access to the water, views, public and cultural spaces, and upgraded transportation corridor.	The project could result in temporary effects on water quality during construction but will likely improve water quality over the long term through (1) retrofit of currently untreated PGIS with, at a minimum, basic water quality treatment best management practices in stormwater sub-basins, and (2) reduction of peak flows and the frequency of CSOs by the application of detention facilities to control runoff from combined sewer sub-basins.
2. *Elliott/Western Connector – Pike Street to Battery Street.* The Elliott/Western Connector will provide a connection from the Alaskan Way surface street to the Elliott Avenue/Western Avenue corridor that provides access to and from Ballard Interbay Northend Manufacturing and Industrial Center and neighborhoods north of Seattle (including Ballard and Magnolia). The connector will be four lanes wide and will provide a grade-separated crossing of the BNSF mainline railroad tracks. Additionally, it will provide local street access to Pike Street and Lenora Street and reintegrate with the street grid at Bell Street, which will improve local street connections in Belltown. The new roadway will include bicycle and pedestrian facilities.	Effects are expected to be similar to those described for project 1.
3, *Seattle Combined Sewer System Upgrades* Seattle intends to construct a new combined sewer overflow storage facility and conveyance system along the central waterfront. (This project could include federal funding.)	This project will improve water quality along the Seattle waterfront by reducing the volume and frequency of combined sewer overflow events.

2.7 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 2.5) to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.5), taking into account the status of the species and critical habitat (Section 2.2), 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 listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminishe the value of designated or proposed critical habitat for the conservation of the species.

2.7.1 Chinook Salmon

The threatened status of Chinook salmon derives from decreased abundance and productivity, reduced diversity, and declining spatial structure. Several populations of Chinook salmon use the

action area for rearing, foraging, and/or migration but the Green/Duwamish and the Skykomish River populations have been found to use the action area the most (Table 3). The Green/Duwamish River population is considered healthy, and the Skykomish River population is considered depressed as the result of low productivity.

Juveniles from the populations using the action area encounter habitat conditions that are degraded by of the presence of a vertical seawall and numerous overwater strutures, leaving little shallow water habitat. Approximately 60 percent of the seawall contains overwater structures, and Chinook salmon have not been found to migrate under the overwater structures, but instead migrate around each one, causing extra energy expenditures and increased risk of predation. A shallow habitat bench is being constructed with the replacement of the seawall, but the project is not expected to be completed until 2020. The lack of shallow water habitat, and shade caused by overwater structures reduce primary productivity and therefore, macroinvertebrates and other prey for Chinook salmon. Extensive urban development and ongoing activities along the Seattle waterfront also impact Chinook salmon habitat as in-water noise (ambient noise) is high due to the high number of ferries, cargo and container ships, barges and other boat traffic. Continued repair and replacement of overwater structures and other development along the seawall frequently causes impacts related to pile driving and water quality. Pile driving activities occurring at the same time as the proposed project will increase background sound levels for Chinook salmon within the project area which may alter their behavior. However, the effects will be minimal. Stormwater discharges regularly add pollutants that have a range of negative effects. Each of these baseline conditions limit the number of juvenile Chinook salmon that can successfully rely on the action area to safely shelter, feed, grow, and develop during their migration. When project effects are added to the baseline, some habitat aspects will be degraded, and some improved. The duration of these effects are both temporary and permanent.

1) Minimal effects from the project will result from the shading caused by the overwater structure, Grating installed along the nearshore minimizes shading effects and improves the migratory corridor for juvenile Chinook salmon.

2) The project will add short-term adverse effects to the baseline water quality condition episodically during construction. Removal of the timber piles and installation of the steel piles will increase contaminants (creosote), turbidity, and suspended solids within 15 meters (50 feet) that will result in adverse effects to a small number of juvenile Chinook salmon.

3) Impact pile driving to construct this project will kill or injure Chinook salmon present in an area up to 48 meters (157 feet) from each pile being installed.

While the Services use the extent of habitat modified from the project to measure the extent of adverse effects on Chinook salmon, we are able to provide an estimate on the potential number of Chinook salmon that may be affected by construction. Adverse effects to Chinook salmon will result from elevated contaminants, turbidity, and suspended solids and increased sound pressure levels from vibratory and impact pile driving. Increased contaminants, turbidity, and suspended solids will result in behavioral changes to 771 juvenile Chinook salmon.

Impact pile driving will have the largest impact to Chinook salmon. Sound pressure level calculations resulted in injury or mortality occurring out to 48 meters (157 feet) from impact pile driving activities. This results in an estimate of 209 juvenile Chinook salmon that may be injured or killed from impact pile driving over the two years of construction.

Chinook salmon within the action area originate from multiple watersheds with 64 percent coming from the Green/Duwamish River and 27 percent coming from the Skykomish River. Of the 209 juvenile Chinook salmon estimated to be injured or killed each year, 134 are expected to originate from the Green/Duwamish River and 57 from the Skykomish River. Both the Green/Duwamish and Skykomish river Chinook salmon populations are rated important for salmon recovery. The Green/Duwamish River Chinook salmon population is considered healthy and the Skykomish River population is depressed.

Chinook salmon early marine survival rates are estimated to be between 0.1 and 2.0 percent. Therefore, for the 209 juvenile Chinook salmon injured or killed from impact pile driving, the adult equivalents that would have returned to spawn is zero to four adults from either the Green/Duwamish River (up to three adults) or the Skykomish River (one adult) populations. The loss of these adults is less than 0.1 percent of the average returning escapement numbers over the last 5 years at both the Green/Duwamish River and the Skykomish River (WDFW 2017).

The existing conditions in the action area already limit growth, maturation, and survival during juvenile outmigration because the overwater structures, lack of shallow water habitat, and water quality conditions all work to impair feeding and predator avoidance, and require extra expenditures of energy. Construction from the proposed project will add a range of additional effects causing behavioral responses, injury, and death of juvenile fish mainly from two populations of Chinook salmon that must rely on a waterway influenced by a highly developed and urbanized action area, where they are exposed to degraded nearshore marine and shoreline habitats. While abundance in the two populations will be negatively affected during construction, based on general rates of juvenile to adult survival, the Services expect overall productivity for these two populations will be only slightly reduced (less than one percent). This slight reduction in productivity is not at a degree or duration expected to reduce the viability of the affected populations. The Services anticipate that when the amount of injury and death during construction is added to the baseline condition, and when cumulative effects of non-federal construction and climate change are factored, the Green/Duwamish and Skykomish River populations will not have an increased risk of being extirpated, and overall risk to the ESU is unchanged.

2.7.2 Bocaccio

The NMFS has not identified biological populations or determined population estimates for bocaccio. However, the total rockfish population has declined for the past several decades. Within Elliott Bay, larval individuals may be found in the nearshore. As bocaccio grow, juveniles settle onto shallow nearshore waters in rocky or cobble substrates with or without kelp. As the fish grow larger they continue to move to deeper waters. Adults occupy waters at depths from 40 to 250 meters (131 to 820 feet).

Threats from bycatch in commercial and recreational harvest and loss and degradation of habitat threaten the species. The habitat conditions for bocaccio are degraded in the project area. Approximately 60 percent of the seawall contains overwater structures, and all large cobble and rocks are riprap placed at the bottom of the seawall to prevent erosion. Vegetation is limited to open areas between the piers, and kelp is scattered along the seawall.

Because of the limited number of bocaccio in Puget Sound, project construction is expected to have adverse effects on very few individuals. Adverse effects will occur through increased turbidity and suspended solids and pile driving activities. The Services anticipate that when the amount of injury and death during construction (up to five larval bocaccio over two years) is added to the baseline condition, and when cumulative effects of non-federal construction and climate change are factored, the bocaccio population will not have an increased risk of being extirpated, and overall risk to the DPS is unchanged.

2.7.3 Killer Whales

The endangered status of the Southern Resident Killer whale DPS is based on low abundance, low productivity, and low diversity. The total population of the Southern Resident killer whales is estimated at 78 individuals. The baseline condition in the action area contributes pollutants that can reach the marine environment at low but chronic levels, and limits carrying capacity for juvenile salmonids which are a primary prey species for the killer whales.

Effects of the action, when added to the baseline, will include direct effects to individual whales, and effects to habitat that will cause indirect effects among the DPS. Specifically, 24 animals are expected to have significantly disrupted behaviors (Level B harassment) as a result of the project between September 1, 2017, and February 28, 2018, primarily a response to underwater noise. This effect among approximately 30.8 percent of the population is not expected to alter annual rates of recruitment or survival among members of the population, because elevated SPLs will not result in injury to any killer whales, but will result in temporary behavioral changes.. The indirect effects of the project are neutral to beneficial. The proposed project's beneficial effects on PS Chinook migration PCEs are likely to incrementally improve habitat for killer whale prey, by improving both water quality and prey base. Therefore, the proposed action is not expected to alter the likelihood of survival or recovery of this species.

2.7.4 Humpback Whales

NMFS has identified three DPSs of humpback whales that are found off the coast and in the inland waters of Washington: Hawaii DPS (not listed), Mexico DPS (threatened), and the Central American DPS (endangered). Abundance estimates for the Mexico DPS and Central America DPS are about 400 individuals and 3,200 individuals, respectively. The baseline condition in the action area contributes pollutants that can reach the marine environment and increased noise and activities that limits use by humpback whales.

Five humpback whales are expected to have significant disruption in normal behaviors as a result of the project between September 1, 2017, and February 28, 2018. We estimate that two of the five humpback whales affected by the project might originate from the Mexico DPS and one

from the Central America DPS. These whales represent less than a half of percentage of the total abundance of each DPS. Since this very low percentage will experience only behavioral effects, rather than injury, it is not expected to impact annual rates of recruitment or survival of the population. Therefore, when added to the baseline and cumulative effects, the proposed action is not expected to alter the likelihood of survival or recovery of this species.

2.7.5 Bull Trout

Anadromous bull trout from several different core areas may be present within the action area. Marine areas within the action area are designated bull trout critical habitat and most likely used by populations from the Stillaguamish, Snohomish-Skykomish, and the Puyallup River core areas for foraging and migration. The Stillaguamish and Puyallup River core areas are ranked as "potentially at risk," while the Snohomish River core area is ranked as "potentially at risk" (USFWS 2008b). The lower Green/Duwamish River is FMO habitat and does not have a spawning population (USFWS 2004a).

The number of bull trout that may be present in the action area and Elliott Bay, is believed to be small. Bull trout have been captured in the Duwamish River indicating that they migrate through Elliott Bay to reach the Duwamish River. One bull trout was radio tracked migrating between the Snohomish River and the Duwamish River during the winter months. This individual bull trout spent little time in Elliott Bay. Another bull trout was observed during snorkeling surveys on the habitat bench at the Olympic Sculpture Park.

Habitat conditions for bull trout within the project area are highly degraded. The project area consists of a vertical seawall with little shallow water habitat. While bull trout are not nearshore dependent, they are found near prey and forage fish within the marine environment. The vertical seawall and habitat conditions do not provide habitat for forage fish spawning. The overwater structures along the seawall also limit primary and macroinvertebrate production, that limits forage fish and salmonid production within the action area.

The Services expect that a small number of bull trout will be exposed. Bull trout are migratory and may be exposed to some construction related impacts such as elevated sound pressure levels during both vibratory and impact pile driving.

Bull trout use of the Elliott Bay nearshore is poorly understood, with only one bull trout being observed along the Olympic Sculpture Park, and other bull trout migrating quickly through Elliott Bay to and from the Duwamish River. Bull trout from the Stillaguamish, Snohomish-Skykomish, and the Puyallup River core areas may forage and migrate through the project area. The Stillaguamish River and Puyallup River core areas are both ranked as "at risk," the Snohomish-Skykomish River core area is ranked as "potential risk." Although some individuals may be injured or killed from project-related effects, we do not expect that the loss of a small number of individuals will measurably reduce the overall population abundance at the scale of the core areas or the Coastal Recovery Unit.

2.7.6 Chinook Salmon Critical Habitat

Critical habitat is severely degraded, with concerns in the action area primarily focused on shoreline conditions, degraded water quality, and limited forage and prey species as the primary baseline factors. The adverse effects on PCEs for Chinook salmon are temporary reduction in water quality and increased sound pressure levels. Based on the relative small proportion of available habitat affected by project activities and the limited duration of effects of the project, the negative impacts to PCEs of the designated critical habitat for Chinook salmon when added to the baseline, will not significantly reduce conservation potential of the critical habitat or degrade the conservation values of the critical habitat.

2.7.7 Bocacio Critical Habitat

The attributes of the nearshore PCEs, where they are present in the action area, are severely degraded. Though habitat in the action area is low functioning, it still provides limited space for migration, growth, and rearing. The proposed project will have limited short-term effects on the nearshore PCE in the action area. After the project is complete, the PCE will recover its function quickly, such that no conservation parameters will be diminished. The magnitude of the effect of the project will be small such that the proposed action will not reduce the value of designated critical habitat for the conservation of the species.

2.7.8 Killer Whale Critical Habitat

Critical habitat is degraded in the action area especially for passage conditions due to the increased underwater sound levels from ferry, barge, and container vessel traffic. The proposed project will increase undewater sound through vibratory and impact pile driving. Increased sound pressure levels will occur throughout the action area within Elliott Bay and Puget Sound, east of Bainbridge Island. Approximatley 512 juvenile Chinook salmon (0.5 to 10 adult equivalence) will either have significant disruption in normal behaviors such as feeding and migration or will be injured or killed due to project construction. However, the project will not reduce the conservation potential or degrade the conservation values of the critical habitat because the action area is a small proportion of available habitat within Puget Sound and ambient sound levels are high due to vessel traffic.

2.8 Conclusion

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the action area, the effects of the proposed action, any effects of interrelated and interdependent activities, and cumulative effects, it is Services' biological opinion that the proposed action is not likely to jeopardize the continued existence of Chinook salmon, bocaccio, killer whales, humpback whales, and bull trout or destroy or adversely modify designated critical habitat for Chinook salmon, bocaccio, and killer whales.

2.9 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 actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering (50 CFR 222.102). 'Harass" is defined as to create 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 (NMFS 2016d, 50 CFR 17.3). "Incidental take" is defined by regulation as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant (50 CFR 402.02). Section 7(b)(4) and 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 ITS.

This opinion includes a prospective ITS for killer whales and humpback whales, however this ITS for these species will not go into effect until the provisions of the MMPA 101(a)(5) are met, and the Terms and Conditions are appended to this ITS, subsequent to the issuance of the IHA under the MMPA.

A marine mammal species or population stock that is listed as threatened or endangered under the ESA is, by definition, also considered depleted under the MMPA. Before incidental take of listed marine mammals may be exempted from the taking prohibition of ESA section 9(a), incidental taking must be authorized under section 101 (a)(5)(D) of the MMPA. The incidental taking will be authorized under section 101(a)(5)(D) of the MMPA if NMFS finds that the taking will have a negligible impact on the species or stocks(s), and will not have an unmitigable adverse impact on the availability of the species or stocks(s) for subsistence uses where relevant.

2.9.1 Amount or Extent of Take

As described in the effects analysis, we anticipate that the action will result in the take of Chinook salmon, bocaccio, killer whales, humpback whales, and bull trout. However, depending on the stressor, when the Services cannot predict the number of an individual fish or marine mammal that will be exposed to a stressor, we use a surrogate in the amount of modified habitat or the physical and temporal extent of the stressor to express the amount of take for the species. This take can be readily observable or measured and therefore suffices to trigger reinitiation of the consultation, if exceeded and necessary.

The presence of the ESA-listed fish and whales within the action area is affected by a complex and interactive mix of biotic and environmental processes that act to randomize their distribution and abundance across temporal and spatial scales. Therefore, the Services cannot predict with meaningful accuracy the number of fish and whales that are reasonably certain to be exposed to elevated noise, contaminants, turbidity, and suspended sediments. Additionally, there is no practical way to count the number of exposed individuals without causing additional stress and

injury. In such circumstances, the Services use the causal link established between the activity and the likely changes in habitat conditions affecting the listed species to describe the extent of take as a numerical level of habitat disturbance.

The best available surrogates for the extent of take from exposure to project-related in-water noise are: the sound sources, and the timing and duration of the noise. These surrogates are proportional to the amount of take because the source determines the nature and intensity of the noise, the timing affects the life stages most likely to be exposed, and the duration is likely to affect the number of individuals that are exposed and the intensity of the impact they may experience. The best available surrogate for the extent of take from exposure to project-related contaminants, turbidity, and suspended sediments is the area of marine habitat that would be enclosed within the silt curtain. This surrogate is would be proportional to the amount of take because fish enclosed within the silt curtain would unable to escape exposure, whereas those outside very unlikely to be exposed.

In the biological opinion, NMFS determined that incidental take is reasonably certain to occur as follows:

Puget Sound Chinook Salmon

Take is expected in the follow forms and extent:

1) Incidental take of Chinook salmon in the form of harassment (significant disruption in normal behaviors such as feeding and migration), injury, or death from elevated contaminants (creosote), turbidity, and suspended sediments (above background conditions) will occur within 15 meters (50 feet) of in-water construction activities or from entrapment from the installation of the sediment curtain. Juvenile Chinook salmon are expected to be harassed, injured, or killed. This form of take is anticipated during pile removal and installation or installation of the sediment curtain that occurs in September and October in 2017 and 2018. The Services estimate that up to 156 juvenile Chinook salmon will be harassed, injured, or killed in 2017 and up to 156 juveniles in 2018 as a result of increased contaminants, turbidity, and suspended sediments. Because the number of individual fish harassed, injured, or killed cannot be effectively monitored, the extent of take is defined as elevated turbidity within 15 meters (50 feet) of in-water construction activities or the area (approximately 91,089 square feet [8,462 square meters], excluding underneath Piers 62/63) within the sediment curtain.

2) Incidental take of Chinook salmon in the form of harm from impact pile driving: The size of the area in which harm of Chinook salmon will occur is within 48 meters (157 feet) radius of impact pile driving. Juvenile Chinook salmon are expected to be harmed. Take is anticipated to occur in September and October, 2018, during impact pile driving of steel piles. The Services estimate that up to 19 Chinook salmon per day for a total of 209 juveniles will be injured or killed from impact pile driving. Because the number of individual fish harmed cannot be effectively monitored, the extent of take is defined as sound exceeding the 205 db_{peak}, 178 dB_{SEL}, or 189 dB_{RMS} thresholds for pile driving

activities which includes an 8 dB reduction in sound levels for the use of a bubble curtain.

Bocaccio

Take is expected in the follow forms and amounts:

1) Incidental take of bocaccio in the form of harassment (significant disruption in normal behaviors such as feeding and migration), injury, or death from elevated contaminants, turbidity, and suspended sediments (above background conditions) will occur within 15 meters (50 feet) of in-water construction activities or from entrapment from the installation of the sediment curtain. Juvenile bocaccio are expected to be harassed, injured, or killed. This form of take is anticipated during pile removal and installation or installation of the sediment curtain that occurs in September and October in 2017 and 2018. The Services estimate that one bocaccio per year will be harassed, injured, or killed in 2017 and 2018. Because the number of individual fish harassed cannot be effectively monitored, the extent of take is defined as elevated turbidity within 15 meters (50 feet) of in-water construction activities or the area (approximately 91,089 square feet [8,462 square meters], excluding underneath Piers 62/63) within the sediment curtain.

2) Incidental take of bocaccio in the form of harm from impact pile driving: The size of the area in which harm of bocaccio will occur is within 48 meters (157 feet) radius of impact pile driving. Juvenile bocaccio are expected to be harmed. Take is anticipated to occur in September and October, 2018, during impact pile driving of steel piles. Because the number of individual fish harmed cannot be effectively monitored, the extent of take is defined as sound exceeding the 204 db_{peak} or 178 dB_{SEL} thresholds for pile driving activities which includes an 8 dB reduction in sound levels for the use of a bubble curtain.

Killer Whales and Humpback Whales

Take is expected in the follow forms and amounts:

1) Incidental take of SR killer whales and humpback whales in the form of harassment resulting from the direct impacts of elevated underwater SPLs resulting from vibratory and impact pile driving: The size of the area in which harassment of SR killer whales and humpback whales will occur is within a 54,117 meter (33.6 mile) radius of pile driving activities or the marine waters of Elliott Bay and Puget Sound from Manchester, just southwest of Bainbridge Island, to Ferncliff on Banbridge Island. Take is anticipated to occur between September 1, 2017, and February 28, 2018, when pile driving activities occur. The Services estimate that up to 24 killer whales and five humpback whales will be harassed during the pile driving activities. Because it is not possible to meaningfully monitor the number of animals harassed, the extent of take is defined as exceeding underwater SPLs described in Table 9 for pile driving activities.

Bull Trout

Take is expected in the follow forms and amounts:

1) Incidental take of bull trout in the form of harm from impact pile driving. The extent of the area where harm of bull trout will occur is within a 48 meter (157 feet) radius of impact pile driving. Juvenile, sub-adult, and adult bull trout are expected to be harmed. Take is anticipated to occur during impact pile driving of steel piles. The Services expect that one bull trout per year will be injured or killed. Because the number of individual fish harmed cannot be effectively determined, the extent of take is defined as the extent to which underwater sound levels exceed the 204 db_{peak} or 178 dB_{SEL} thresholds for pile driving activities within a 48 meter (157 feet) radius of pile driving activities which includes an 8 dB reduction in sound levels for the use of a bubble curtain.

2.9.2 Effect of the Take

In the biological opinion, the Services determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

2.9.3 Reasonable and Prudent Measures

"Reasonable and prudent measures" are nondiscretionary measures that are necessary or appropriate to minimize the impact of the amount or extent of incidental take (50 CFR 402.02).

The proposed action incorporates minimizations measures, construction BMPs, and monitoring requirements. The Services determined that full application of these measures will minimize the extent of incidental take to the maximum practicable. Therefore, the Services prescribe a single RPM to ensure that the COE will not exceed the estimated amount of take in Section 2.9.1 of this statement. Full application of conservation measures included as part of the proposed action, together with use of the reasonable and prudent measures and terms and conditions described below, are necessary and appropriate to minimize the impact of incidental take of listed species from the proposed action.

The COE shall:

1. Ensure completion of a monitoring and reporting program to confirm that the take exemption for the proposed action is not exceeded, and that the terms and conditions in this incidental take statement are effective in minimizing incidental take from permitted activities.

2.9.4 Terms and Conditions

The terms and conditions described below are non-discretionary, and the COE or any applicant must comply with them in order to implement the RPMs (50 CFR 402.14). The COE or any applicant has a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this ITS (50 CFR 402.14). If the entity to whom a term and condition is directed does not comply with the following terms and conditions, protective coverage for the proposed action will likely lapse.

1. The following term and condition implements reasonable and prudent measure 1:

   In order to monitor the take exemption the COE shall ensure that the applicant prepares an annual report identifying any incidental take associated with project activities and describing conservation measures implemented to minimize take. The report shall include a description of construction activities conducted and duration of activities to ensure take was not exceeded. The report shall be submitted to the both the USFWS and NMFS' offices in Lacey, Washington, within 6 months of completion of construction each year. The report shall summarize the compliance with the project description and conservation measures and the level of exempted incidental take during the implementation of the project that year.

   a. The report shall include the following:
      - Results of water quality monitoring during construction.
        - Turbidity monitoring will occur at 50 feet from sediment generating activities at two locations within the water column.
        - Monitoring will occur every half hour during sediment generating activities. If after 4 hours no exceedances of water quality standards occur, monitoring can be reduced to every 2 hours for the remainder of the day. If no exceedances occur after one day, monitoring can be reduced to 2 samples per day. Visual monitoring can be conducted as part of regular construction management inspections and water quality monitoring occurs if there is a visible turbidity plume indicating excessively high turbidity and suspended solids levels.
        - If turbidity levels exceed background levels at 50 feet, then the amount of take authorized by the Incidental Take Statement will have been exceeded.
      - Results of the marine mammal monitoring during construction.
      - Results of the acoustic monitoring during pile driving activities. Acoustic monitoring is to identify and confirm pile driving noise levels.
        - If peak, SEL, and RMS dB levels exceed the values the applicant provided to the Services, or the Services thresholds identified in section 2.5, then the amount of take authorized by the Incidental Take Statement will have been exceeded.
      - Dates of construction related activities such as:
        - Removal of the timber piles.
        - Installation of the steel piles.
      - Description of pile driving activities such as:
        - Number and method of timber piles removed.

    - Number of piles installed with an impact pile driver.
    - Number and duration of strikes per pile and throughout the day.
b. The COE shall notify the Services immediately if the results of this program trigger any of the relevant reinitiation requirements specified in the Reinitiation of Consultation section of this opinion (Section 2.11).

2.10 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. Specifically, conservation recommendations are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02).

The Services are not providing any conservation recommendations at this time.

2.11 Reinitiation of Consultation

This concludes formal consultation for the Pier 62 Reconstruction Project.

As 50 CFR 402.16 states, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained or is authorized by law and if: (1) The amount or extent of incidental taking specified in the ITS is exceeded, (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion, (3) the agency action is subsequently modified in a manner that causes an effect on the listed species or critical habitat that was not considered in this opinion, or (4) a new species is listed or critical habitat designated that may be affected by the action.

2.12 "Not Likely to Adversely Affect" Determinations

The applicable standard to find that a proposed action is not likely to adversely affect listed species or critical habitat is that all of the effects of the action are expected to be discountable, insignificant, or completely beneficial. Beneficial effects are contemporaneous positive effects without any adverse effects to the species or critical habitat. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Discountable effects are those extremely unlikely to occur.

The Services analyzed the potential impacts of the project on Puget Sound (PS) steelhead, yelloweye rockfish, yelloweye critical habitat, marbled murrelet, and bull trout critical habitat and determined that the impacts will be discountable and/or insignificant. Based on this analysis, the Services concur with the COE that the proposed action is not likely to adversely affect the subject listed species and designated critical habitats

2.12.1 Puget Sound Steelhead

Having an anadromous life history form, steelhead, especially from the Green/Duwamish River and those populations south of Elliott Bay, will use the action area as they migrate out to the ocean. Steelhead populations south of Elliott Bay include the Puyallup, Nisqually, and the Deschutes River populations and smaller streams that enter directly into Puget Sound such as Clover and Woodland creeks. Smolts and adults spend little time in estuaries, migrating quickly to deeper waters (Emmett et al 1991).

Juvenile steelhead migration out of the Green/Duwamish River occurs from March through July (Williams et al 2001). Size range of steelhead migrating out of the Green/Duwamish River was 42 to 490 mm (mean fork length was 257.75 mm) comprised of multiple year classes (Brennan et al 2004). The small number of steelhead caught suggests that steelhead rapidly migrate through the lower Duwamish and estuary (Ruggerone et al. 2006). The migration pattern of steelhead in Puget Sound is not well known; however, once entering the marine environment, it is believed that steelhead smolts move quickly offshore to deeper water (Hartt and Dell 1986).

Summer-run adult steelhead migrate up the Duwamish/Green River from April through October, and winter-run adults from November through May (Williams et al 2001). The winter-run population is the larger population and is composed of both hatchery and wild stocks. The summer-run population is composed almost entirely of hatchery stock. Repeat spawners have been found to compose from 0 percent to 20 percent of the returning wild adults (Williams et al 2001). The summer-run population was considered depressed in 2002 with a long-term negative trend and a short-term severe decline (WDFW 2002a). The winter-run population was rated healthy because of a consistent spawner escapement around the goal of 2,000 wild spawners (WDFW 2002b). Since 2004, the winter-run natural spawner counts has decreased by 23 percent with natural spawners counts between 2000-2004 being 1,693, decreasing to 552 in 2010-2014 (NWFSC 2015).

The number of steelhead caught or observed within the action area is low. No steelhead were observed during the October 2011 to May 2013 fish surveys along the seawall (Toft et al. 2012a, 2012b, 2012c, 2012d, 2013a, 2013b). Steelhead have been observed south of Elliott Point, near Golden Gardens, in Shilshole Bay, at Alki Point, and within Elliott Bay at the mouth of the Duwamish River (Williams et al 2001). In a study of the nearshore habitat in WRIAs 8 and 9 (including Vashon and Maury Islands), 591 beaches were sampled by seining in 2001 and 2002, almost 34,000 salmonids were caught and only nine were steelhead (Brennan et al. 2004). These steelhead were captured from May through August with no steelhead caught in April, September, October, or December.

Because steelhead are not shoreline dependent and quickly migrate to deeper water and to the ocean, they will not be exposed to project construction effects, and future cohorts' exposure to long-term effects will be ephemeral. While increased turbidity and suspended solids extends only 15 meters (50 feet) from in-water construction activities (see Adverse Effects Section, Elevated Turbidity and Supended Sediment) and increased sound pressure levels from impact pile driving resulting in injury (187 dBSEL for fish greater than two grams, see Adverse Effects Section, Injury and Death of Fish from Impact Pile Driving) extends 48 meters (157 feet) from

construction, exposure to these habitat effects is not expected. Because steelhead move to deeper water and migrate to the ocean quickly, they will likely avoid the areas where increased turbidity and injurious sound pressure levels will occur. Increased sound pressure levels that may result in behavioral changes to steelhead extend 2,929 meters (1.8 miles) from vibratory and impact pile driving activities (see Adverse Effects Section, Behavioral Responses of Fish to Elevated Underwater SPLs). Similarly, since steelhead migrate to the ocean quickly, elevated sound levels will not affect the behavior of steelhead to the degree that injury will occur. Therefore, the effects of the project to steelhead are expected to be insignificant.

2.12.2 Yelloweye Rockfish

Yelloweye rockfish were listed as threatened under the ESA on April 28, 2010 (75 FR 20802). The final rule listing yelloweye rockfish identified several primary factors for their decline, including: overutilization for commercial and recreational purposes, habitat degradation, water quality problems including low dissolved oxygen and elevated contaminant levels, and inadequacy of existing regulatory mechanisms.

Unlike canary rockfish and bocaccio, yelloweye rockfish are not known to occupy intertidal or shallow water habitats (Love 2011, Sudebaker et al. 2009). Juvenile yelloweye rockfish ultimately settle in 100 to 130 feet of water, near the upper end of the depth range occupied by adult yelloweye rockfish (Love 2011). Yelloweye rockfish are found most frequently in north Puget Sound (west and north of Whidbey Island around the San Juan Islands). Yelloweye rockfish have been caught by anglers near Mukilteo and Bainbridge Island (Palsson et al. 2009).

Juvenile and adult yelloweye rockfish settle in waters greater than 100 feet, and this greatly diminishes any potential for exposure to effects of the proposed action. Increased turbidity and suspended solid effects extend only 15 meters (50 feet) from in-water construction activities (see Section 2.5) and increased sound pressure levels from impact pile driving resulting in injury extends 48 meters (157 feet) from construction. From bathymetry data (USGS 2016), the 48-meter distance appears to reach the approximate 100 foot depth in Elliott Bay. Therefore, exposure to construction effects beyond the 100 foot depth and exposure to yelloweye rockfish is not expected. While increased sound pressure levels that may result in behavioral changes to yelloweye rockfish extend 2,929 meters (1.8 miles) from vibratory and impact pile driving activities, the Services assume that sound travels in a straight line and does not bend or reflect and travel in a different direction. Because of the depth and habitat, substrate, and rugosity of where yelloweye rockfish are found, they will not be exposed to the increased sound levels that will affect the behavior of yelloweye rockfish to the degree that injury will occur. Therefore, the effects of the project to yelloweye rockfish are expected to be insignificant.

2.12.3 Marbled Murrelet

The marine environment is important for marbled murrelets year round. Many prey species for marbled murrelets are concentrated in nearshore waters where freshwater or estuaries provide spawning and rearing areas (USFWS 1997, p. 30). The marine environment and action area are used by marbled murrelets for foraging, loafing, stretching, preening, breeding, rearing, and social interactions.

The action area lies within Conservation Zone 1, Stratum 3, of the marbled murrelet monitoring program. Zone 1 includes the Strait of Juan De Fuca, Puget Sound, Hood Canal, and the San Juan Islands. Stratum 3 includes south Hood Canal and central/south Puget Sound. In 2015, the marbled murrelet population estimate in Zone 1 was 4,290 birds, with an annual rate of decline of 5.3 percent between 2001 and 2015 (Lance and Pearson 2016, p. 4). Marbled murrelet population estimates based on surveys conducted in stratum 3 was 238 marbled murrelets (density 0.16 birds per km^2) in 2014, and 94 marbled murrelets (density 0.06 birds per km^2) in 2015 (Lance and Pearson 2016, p. 4; Lynch et al. 2016, pp. 10-13).

Marbled murrelet use of Elliott Bay is very rare. Elliott Bay has an industrialized urban waterfront with significant vessel (container barge, ferries, cruise ships, etc.) traffic and very limited forage fish spawning habitat and foraging opportunities. Two marbled murrelets were seen by a trained observer in front of the grain elevators near Myrtle Edwards Park in 2012, north of downtown Seattle and the project location (Teachout, in litt. 2012). The observer thought it may have been the same bird, but that is undetermined. The bird(s) was constantly diving which is an indication of active foraging. The observations were approximately one mile north of the project site in an area where the shoreline is less industrialized. Occasional marbled murrelet sightings are reported in and around Elliott Bay on ebird (internet site at www.ebird.com), but the sources and validity of these reports are uncertain. Given the lack of natural shoreline and intertidal habitat along the heavily industrialized waterfront, the Services do not expect many marbled murrelets to be present in the vicinity of the seawall during or after construction.

The Services expect the effects of the project to marbled murrelets to be discountable because the following conditions inhibit murrelets from using the action area: 1) work will be conducted along the Seattle waterfront where there is limited open water (less than 35 percent open water) due to extensive overwater structures; and 2) the project area has high levels of human activity and disturbance associated with marine traffic such as ferries, barges, cargo and cruise ships, and nearshore traffic including cars, trucks, buses, trams, pedestrians, etc.

2.12.4 Yelloweye Rockfish Critical Habitat

The NMFS designated critical habitat for yelloweye rockfish on November 13, 2014 (79 FR 68041). The PCE for yelloweye rockfish critical habitat in the action area includes:

- Deepwater Critical Habitat: Juvenile and adult yelloweye rockfish. Sites deeper than 98 feet (30 m) that possess (or are adjacent to) areas of complex bathymetry. These features are essential to conservation because they support growth, survival, reproduction, and feeding opportunities by providing the structure to avoid predation, seek food, and persist for decades. Deepwater attributes include: 1) quantity, quality, and availability of prey species to support individual growth, survival, reproduction, and feeding opportunities; 2) water quality and sufficient levels of dissolved oxygen to support growth, survival, reproduction, and feeding opportunities; and 3) structure and rugosity to support feeding opportunities and predator avoidance.

The proposed action will not measurably effect deepwater attributes for juvenile and adult yelloweye rockfish. Increased turbidity and suspended solid effects extend only 15 meters (50 feet) from in-water construction activities (see Section 2.5) and increased sound pressure levels from impact pile driving resulting in injury extends 48 meters (157 feet) from construction. From bathymetry data (USGS 2016), the 48-meter distance appears to reach the approximate 98 foot depth in which yelloweye rockfish critical habitat begins. Therefore, the construction effects including increased turbidity, suspended sediments, and sound pressure levels that could result in injury do not extend in yelloweye critical habitat and will not affect the PCEs or deepwater attributes. Increased sound pressure levels that result in significant behavioral changes extend 2,929 meters (1.8 miles) from the project site and does extend into yelloweye critical habitat. However, this increased sound will not result in a measurable change to any of the deepwater attributes essential to yelloweye rockfish. Therefore, the potential effects to yelloweye rockfish critical habitat are insignificant.

2.12.5 Bull Trout Critical Habitat

The USFWS designated critical habitat for the Coastal Recovery Unit bull trout on October 18, 2010 (75 FR 63898). Five of the nine PCEs of bull trout critical habitat are in the action area:

- PCE #2: Migration 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.

- PCE #3: An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.

- PCE #4: Complex river, stream, lake, reservoir, and marine shoreline aquatic environments, and processes that establish and maintain these aquatic environments, with features such as large wood, side channels, pools, undercut banks and unembedded substrates, to provide a variety of depths, gradients, velocities, and structure.

- PCE #5: Water temperatures ranging from 2 °C to 15 °C (36 °F to 59 °F), with adequate thermal refugia available for temperatures that exceed the upper end of this range. Specific temperatures within this range will depend on bull trout life-history stage and form; geography; elevation; diurnal and seasonal variation; shading, such as that provided by riparian habitat; streamflow; and local groundwater influence.

- PCE #8: Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.

The proposed action will affect the PCEs listed below. The project will have no effects on PCE #5, water temperatures. The Services expect a range of effects – both positive and negative – as a consequence of the proposed action.

PCE #2: Migration Corridor – The action may temporarily introduce an impediment or barrier within migration habitat; however, effects will be temporary and will not preclude bull trout movement through the area during or after construction. Increased turbidity and suspended solids from pile driving activities to remove the timber piles and install the steel piles will disrupt normal behavior and bull trout migration along the seawall as the fish alter their route to avoid turbidity plumes. Turbidity and suspended solids are expected to be temporary and episodic during construction and will not preclude bull trout from moving through the action area. Increased sound pressure levels from both vibratory and impact pile driving will result in disruption of normal migratory behaviors within the action area. High sound levels will be intermittent, and bull trout will still be able to migrate through the action area during the daytime between pile proofing and at night when pile driving is not occurring. Over the long-term, replacing the nearshore overwater structure with grating, in conjunction with the habitat bench being installed for the Seawall Replacement Project will improve the migratory corridor through the project area.

We do not anticipate that temporary impacts to the migratory corridor from these stressors will measurably affect this PCE because they will not prevent bull trout from moving through the action area during or after construction. Because the project will not preclude bull trout from moving through the area and will not impair the function of the migratory corridor over the long-term, effects to this PCE are considered insignificant.

PCE #3: Abundant Food Base – Project construction will result in a short-term temporary reduction in prey abundance. Pile removal and installation will result in macroinvertebrates and juvenile salmonids being displaced and killed as well as their habitat altered or destroyed. Pile removal and installation will also result in increased turbidity and suspended sediments that will result in the loss of prey species. However, macroinvertebrates will quickly recolonize the disrupted areas from the surrounding area. Because the project will not result in a long-term reduction in prey abundance, effects to this PCE are considered insignificant.

PCE #4: Complex Habitat - The project replaces the existing overwater structure with a similar structure that maintains the degrade conditions of the habitat by continuing to preclude and/or degrade natural shoreline/riparian processes. Therefore, the effects to this PCE are considered insignificant.

PCE #8: Water Quality and Quantity – Removal of the timber piles and installation of the steel piles will each increase turbidity and suspended solids that will temporarily degrade water quality conditions within the project area. Because construction-related impacts to water quality (turbidity and suspended sediments) will be short-term and will not impair the function of this PCE, we do not expect the action to result in measurable effects to this PCE over the long-term. The effects to this PCE are considered insignificant.

3. 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. The MSA (section 3) defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." 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 CFR 600.810). Section 305(b) also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH.

This analysis is based, in part, on the EFH assessment provided by the COE and descriptions of EFH for Pacific Coast groundfish (PFMC 2005), coastal pelagic species (CPS) (PFMC 1998), Pacific Coast salmon (PFMC 2014); and highly migratory species (HMS) (PFMC 2007) contained in the fishery management plans developed by the PFMC and approved by the Secretary of Commerce.

3.1 Essential Fish Habitat Affected by the Project

The proposed action and action area for this consultation are described above in Sections 1.2 (Proposed Action) and 1.3 (Action area). The action area includes areas designated as EFH for various life-history stages of 31 species of Pacific coast groundfish, four species of coastal pelagics, and three species of Pacific salmon (Table 11). The EFH guidelines also identify habitat areas of particular concern (HAPC) based on their importance of ecological function, extent of habitat sensitivity to human degradation, stress associated with developmental activities and rarity of the habitat. Seagrass is identified as the HAPC for Elliott Bay. No HAPCs are identified for freshwater.

Table 11. Essential fish habitat species and life history stage associated with shallow nearshore water in Puget Sound.

Scientific Name	Common Name	Adult	Juvenile	Larvae	Egg
Groundfish Species					
Anoplopoma fimbria	Sablefish	X	X	X	X
Citharichthys sordidus	Pacific sanddab	X			
Eopsetta jordani	Petrale sole	X			
Glyptocephalus zachirus	Rex sole	X			
Hexagrammos decagrammus	Kelp greenling	X		X	
Hippoglossoides elassodon	Flathead sole	X			
Hydrolagus colliei	Spotted ratfish	X	X		
Isopsetta isolepis	Butter sole	X			
Lepidopsetta bilineata	Rock sole	X			
Merluccius productus	Pacific hake	X	X		
Ophiodon elongates	Lingcod			X	
Parophrys vetulus	English sole	X	X		
Platichthys stellatus	Starry flounder	X	X		
Psettichthys melanostictus	Sand sole	X	X		
Raja binoculata	Big skate	X			
Raja rhina	Longnose skate	X	X		X
Scorpaenichthys marmoratus	Cabezon	X	X	X	X
Sebastes auriculatus	Brown rockfish	X			
Sebastes caurinus	Copper rockfish	X	X		
Sebastes diploproa	Splitnose rockfish		X	X	
Sebastes entomelas	Widow rockfish		X		
Sebastes flavidus	Yellowtail rockfish	X			
Sebastes maliger	Quillback rockfish	X	X		
Sebastes melanops	Black rockfish	X	X		
Sebastes mystinus	Blue rockfish	X	X	X	
Sebastes nebulosus	China rockfish	X	X		
Sebastes nigrocinctus	Tiger rockfish	X			
Sebastes paucispinis	Bocaccio		X	X	
Sebastes pinniger	Canary Rockfish		X	X	
Sebastes ruberrimus	Yelloweye rockfish			X	
Squalus acanthias	Spiny dogfish	X			
Coastal Pelagic Species					
Engraulis mordax	Anchovy	X	X	X	X
Sardinops sagax	Pacific sardine	X	X	X	X
Scomber japonicas	Pacific mackerel	X			
Loligo opalescens	Market squid	X	X	X	
Pacific Salmon					
Oncorhynchus tshawytscha	Chinook salmon	X	X		
Oncorhynchus kisutch	Coho salmon	X	X		
Oncorhynchus gorbuscha	Pink salmon	X	X		

3.2 Adverse Effects on Essential Fish Habitat

Based on information provided in the BA and the analysis of effects presented in the opinion portion of this document (Section 2.5), NMFS concludes that the proposed action will have adverse effects on the EFH of several species listed in Table 11. Adverse effects include:

- Elevated underwater sound.
- Water quality impacts from increased turbidity and suspended solids during construction.
- Entrapment of EFH species within the sediment curtain limiting access to available nearby habitat.

3.3 Essential Fish Habitat Conservation Recommendations

Although NMFS expects pile driving activities to generate turbidity levels and sound that are sufficient to reduce the quality of EFH for the various life-history stages of 31 species of Pacific coast groundfish, four species of coastal pelagics, and three species of Pacific salmon, the proposed action includes the best known technology for minimizing turbidity and sound impacts, and there are no reasonable measures to further reduce the level of these effects. Therefore, NMFS does not recommend any additional measures to address this effect.

Because the conservation measures, and BMPs that the COE included as part of the proposed action to address ESA concerns are also adequate to avoid, minimize, or otherwise offset adverse impacts to EFH, additional conservation recommendations pursuant to MSA (§305(b)(4)(A)) are not necessary.

3.4 Statutory Response Requirement

Since NMFS is not providing conservation recommendations at this time, no 30-day response from the COE is required.

3.5 Supplemental Consultation

The COE must reinitiate EFH consultation with NMFS 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 NMFS' EFH Conservation Recommendations (50 CFR 600.920(l)).

4. DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

The Data Quality Act (DQA) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

4.1 Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended user of this opinion is the COE. Other interested users could include the City of Seattle or others interested in the conservation of the affected ESUs/DPS. Individual copies of this opinion were provided to the COE. The format and naming adheres to conventional standards for style.

4.2 Integrity

This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

4.3 Objectivity

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA regulations, 50 CFR 402.01 et seq., and the MSA implementing regulations regarding EFH, 50 CFR 600.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the References section. The analyses in this opinion and EFH consultation contain more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA and MSA implementation, and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

5. REFERENCES

Abbott RR, Bing-Sawyer E, Blizard R. 2002. Administrative Draft - Assessment of Pile Driving Impacts on the Sacramento blackfish (*Orthodon microlepidotus*). Oakland, California: Caltrans. 17 p.

ACA (Alberta Sustainable Resource Development and Alberta Conservation Association). 2009. Status of the bull trout (*Salvelinus confluentus*) in Alberta: Update 2009. Alberta Sustainable Resource Development. Wildlife Status Report No. 39 (Update 2009). Edmonton, Alberta.

Anchor Environmental (Anchor Environmental, L.L.C.). 2003. Literature Review of Effects of Resuspended Sediments Due to Dredging Operations. Prepared for the Los Angeles Contaminated Sediments Task Force, Los Angeles, California. June.

Anchor Environmental. 2004. Marine Shoreline Inventory Report, WRIA 9. Prepared for Seattle Public Utilities, WRIA 9. March.

Anchor QEA. 2011. Survey of Aquatic Habitats and Biological Communities along the Elliott Bay Seawall. Submitted to City of Seattle Department of Transportation. Submitted by Tetra Tech, Inc., Seattle, Washington. March. Document No. 02ENVAQECO-RPT002F-B1.

Anchor QEA. 2012. Elliott Bay Fish Survey Study. Submitted to City of Seattle Department of Transportation. Submitted by Tetra Tech, Inc., Seattle, Washington. April.

Ardren, W. R., P. W. DeHaan, C. T. Smith, E. B. Taylor, R. Leary, C. C. Kozfkay, L. Godfrey, M. Diggs, W. Fredenberg, and J. Chan. 2011. Genetic structure, evolutionary history, and conservation units of bull trout in the coterminous United States. Transactions of the American Fisheries Society 140:506-525. 22 pp.

Au, W.W.L., and M.C. Hastings. 2008. Principles of Marine Bioacoustics. New York: Springer.

Bailey, M. R., Dalecki, D., Child, S. Z., Raeman, C. H., Penney, D. P., Blackstock, D. T., and Carsentensen, E. L. (1996). "Bioeffects of positive and negative acoustic pressures *in vivo*." J Acoust. Soc. Am. 100, 3941-3946.

Baker, E.T. 1982. Suspended particulate matter in Elliott Bay. Puget Marine Environmental Laboratory: NOAA Technical Report ERL 317-PMEL 35.

Baker, C. S., L. Medrano-Gonzalez, J. Calambokidis, A. Perry, F. Pichler, H. Rosenbaum, J. M. Straley, J. Urban-Ramirez, M. Yamaguchi, and O. von Ziegesar. 1998. Population structure of nuclear and mitochondrial DNA variation among humpback whales in the North Pacific. Mol. Ecol. 7:695-708.

Barlow, J., J. Calambokidis, E. A. Falcone, C. S. Baker, A. M. Burdin, P. J. Clapham, J. K. B. Ford, C. M. Gabriele, R. LeDuc, D. K. Mattila, T. J. Quinn II, L. Rojas-Bracho, J. M. Straley, B. L. Taylor, J. Urbán R., P. Wade, D. Weller, B. H. Witteveen, and M. Yamaguchi. 2011. Humpback whale abundance in the North Pacific estimated by photographic capture-recapture with bias correction from simulation studies. Marine Mammal Science. 27:793-818.

Bash, J., C.H. Berman, and S. Bolton. 2001. Effects of turbidity and suspended solids on salmonids. Center for Streamside Studies, University of Washington, Seattle, WA, November 2001. 72 pp.

Battin, J., M.W. Wiley, M.H. Ruckelshaus, R.N. Palmer, E. Korb, K.K. Bartz, and H. Imaki. 2007. Projected impacts of climate change on salmon habitat restoration. Proceedings of the National Academy of Sciences of the United States of America 104(16):6720-6725.

Baxter, C.V. 2002. Fish movement and assemblage dynamics in a Pacific Northwest riverscape. Doctoral dissertation. Oregon State University, Corvallis, OR. 174 pp.

Baxter, J. S. 1997. Aspects of the reproductive ecology of bull trout in the Chowade River, British Columbia. Master's thesis. University of British Columbia, Vancouver. 110 pp.

Bettridge, S., C.S. Baker, J. Barlow, P.J. Clapham, M. Ford, D. Gouveia, D.K. Mattila, R.M. Pace III, P.E. Rosel, G.K. Silber, and PR. Wade. 2015. Status Review of the Humpback Whale (Megaptera Novaeangliae) Under the Endangered Species Act. NOAA-TM-NMFS-SWFSC-540. March 2015. 236 pp.

Beauchamp, D.A., D.E. Pflug, and G. Lucchetti. 1987. Snohomish River juvenile salmon outmigration study 1987. The Tulalip Tribe and Northwest Enviro-Metric Services, Vashon, WA. Navy contract No. N62474-86-C-0991. 108 p.

Beauchamp, D.A., and J.J. VanTassell. 2001. Modeling seasonal trophic interactions of adfluvial bull trout in Lake Billy Chinook, Oregon. Transactions of the American Fisheries Society 130:204-216.

Behnke, R.J. 2002. Trout and Salmon of North America; Chapter: Bull Trout. Free Press, Simon and Shuster, Inc. N.Y., N.Y. Pp. 293-299.

Berkeley, S. A., C. Chapman, and S. M. Sogard. 2004. Maternal age as a determinant of larval growth and survival in a marine fish, *Sebastes melanops*. Ecology 85:1258-1264

Beschta, R.L., R.E. Bilby, G.W. Brown, L.B. Holtby, and T.D. Hofstra. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. Pages 191-232 in E.D. Salo and T.W. Cundy (eds). Streamside Management Forestry and Fisheries Interactions. Institute of Forest Resources, University of Washington, Seattle, Washington, Contribution No. 57. 46 pp.

Bisson, P.A., B.E. Rieman, C. Luce, P.F. Hessburg, D.C. Lee, J.L. Kershner, G.H. Reeves, and R.E. Gresswell. 2003. Fire and aquatic ecosystems of the western USA: Current knowledge and key questions. Forest Ecology and Management. 178 (2003) 213-229. 17 pp.

Boag, T.D. 1987. Food habits of bull char (*Salvelinus confluentus*), and rainbow trout (*Salmo gairdneri*), coexisting in a foothills stream in northern Alberta. Canadian Field-Naturalist 101(1):56-62.

Bobko, S. J. and S. A. Berkeley. 2004. Maturity, ovarian cycle, fecundity, and age-specific parturition of black rockfish, (*Sebastes melanops*). Fishery Bulletin, U.S. Volume 102, pages 4180 to 4429.

Boehlert, G. W., W. H. Barss, and P. B. Lamberson. 1982. Fecundity of the widow rockfish, *Sebastes entomelas*, off the coast of Oregon. Fishery Bulletin, U.S. Volume 80, pages 881 to 884.

Bond, C.E. 1992. Notes on the nomenclature and distribution of the bull trout and the effects of human activity on the species. Pages 1-4 *In* P.J. Howell, and D.V. Buchanan, eds. Proceedings of the Gearhart Mountain bull trout workshop, Oregon Chapter of the American Fisheries Society, Corvallis, OR.

Bonneau, J.L., and D.L. Scarnecchia. 1996. Distribution of juvenile bull trout in a thermal gradient of a plunge pool in Granite Creek, Idaho. Transactions of the American Fisheries Society 125(4):628-630.

Brenkman, S.J., and S.C. Corbett. 2005. Extent of anadromy in bull trout and implications for conservation of a threatened species. North American Journal of Fisheries Management 25:1073-1081.

Brennan, J.S., K.F. Higgins, J.R. Cordell and L.A. Stamatiou. 2004. Juvenile salmon composition, timing, distribution, and diet in marine nearshore waters of central Puget Sound in 2001–2002. King County, Department of Natural Resources and Parks, Seattle Washington. 164 pp.

Brewin, P.A., and M.K. Brewin. 1997. Distribution maps for bull trout in Alberta. Pages 209-216 *In* W.C. Mackay, M.K. Brewin, and M. Monita, eds. Friends of the Bull Trout Conference Proceedings, Bull Trout Task Force (Alberta), c/o Trout Unlimited, Calgary.

Brown, S. J. Wieland, M. Martz, J. Shannon, and H. Page. 2011. Preliminary Results of the Elliott Bay Seawall Fish Survey. Technical Memorandum to Jim Muck, USFWS/NMFS Liaison. August 2, 2011.

Brunner, K., 1999a. Meeting notes from December 12, 1999, Minutes of Third Bull Trout Working Group Meeting. Communication from Doug Hotchkiss, Port of Seattle. Seattle District, U.S. Army Corps of Engineer.

Brunner, K., 1999b. Meeting notes from November 4, 1999, Minutes of the First Bull Trout Working Group Meeting. Communication from Doug Hotchkiss, Port of Seattle. Seattle District, U.S. Army Corps of Engineer.

Buchanan, D.V., and S.V. Gregory. 1997. Development of water temperature standards to protect and restore habitat for bull trout and other cold water species in Oregon. Pages 119-126 *In* W.C. Mackay, M.K. Brewing, and M. Monita, eds. Friends of the Bull Trout Conference Proceedings, , Alberta, Canada.

Buchanan, D.V., M.L. Hanson, and R.M. Hooton. 1997. Status of Oregon's bull trout. Oregon Department of Fish and Wildlife. 168 pp.

Buktenica, M. W., D. K. Hering, S. F. Girdner, B. D. Mahoney, and B. D. Rosenlund. 2013. Eradication of nonnative brook trout with electrofishing and antimycin-A and the response of a remnant bull trout population. North American Journal of Fisheries Management 33:117-129.

Burkey, T.V. 1989. Extinction in nature reserves: the effect of fragmentation and the importance of migration between reserve fragments. Oikos 55:75-81. 7 pp.

Burkey, T.V. 1995. Extinction rates in archipelagoes: Implications for populations in fragmented habitats. Conservation Biology 9: 527-541. 16 pp.

Burns, R. 1985. The shape and forms of Puget Sound. Published by Washington Sea Grant, and distributed by the University of Washington Press. 100 pages.

Cailliet, G. M., E. J. Burton, J. M. Cope, and L. A. Kerr (eds.). 2000. Biological characteristics of nearshore fishes of California: A review of existing knowledge. Final Report and Excel Data Matrix, Pacific States Marine Fisheries Commission. California Department of Fish and Game.

Calambokidis, J. E.A. Falcone, T.J. Quinn, A.M. Burdin, P.J. Clapham, J.K.B. Ford, C.M. Gabriele, R. LeDuc, D. Mattila, L. Rojas-Bracho, J.M. Straley, B.L. Taylor, J. Urbán R., D. Weller, B.H. Witteveen, M. Yamaguchi, A. Bendlin, D. Camacho, K. Flynn, A. Havron, J. Huggins, and N. Maloney. 2008. SPLASH: Structure of Populations, Levels of Abundance and Status of Humpback Whales in the North Pacific. Final report for Contract AB133F-03-RP- 00078 U.S. Dept of Commerce Western Administrative Center, Seattle, Washington.

Caldwell, N. 2016. Phone conversation between Jim Muck (USFWS/NMFS) and Neil Caldwell (Marine Exchange of Puget Sound) regarding the number of vessels (deep draft vessels) that utilize Elliott Bay.

Carlson, T.J., G. Ploskey, R.L. Johnson, R.P. Mueller, M.A. Weiland, and P.N. Johnson. 2001. Observations of the behavior and distribution of fish in relation to the Columbia River navigation channel and channel maintenance activities. U.S. Army Corps of Engineers, PNNL-13595, Portland, Oregon, October 2001. 38 pp.

Carr, M. H. 1983. Spatial and temporal patterns of recruitment of young of the year rockfishes (genus *Sebastes*) into a central California kelp forest. Master's thesis, San Francisco State University, San Francisco, CA, 104 pages.

Carretta, J.V., K.A. Forney, E.M. Oleson, D.W. Weller, A.R. Lang, J. Baker, M.M. Muto, B. Hanson, A.J. Orr, H. Huber, M.S. Lowry, J. Barlow, J.E. Moore, D. Lynch, L. Carswell, and R.L. Brownell Jr. 2017. U.S. Pacific Marine Mammal Stock Assessments: 2016. U.S. Department of Commerce, NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-577. 414 pp.

Carretta, J.V., M.M. Muto, S. Wilkin, J. Greenman, K. Wilkinson, M. DeAngelis, J. Viezbicke, and J. Jannot. 2016. Sources of Human-Related Injury and Mortality for U.S. Pacific West Coast Marine Mammal Stock Assessments, 2010-2014. NOAA-TM-NMFS-SWFSC-554. March 2016. 105 pp.

Cavender, T.M. 1978. Taxonomy and distribution of the bull trout, *Salvelinus confluentus* (Suckley), from the American Northwest. California Fish and Game 64(3):139-174.

Cederholm, C.J., and L.M. Reid. 1987. Impact of forest management on coho salmon (*Oncorhynchus kisutch*) populations of the Clearwater River, Washington: A project summary. Pages 373-398 *In* E.O. Salo, and T.W. Cundy, eds. Streamside management: Forestry and fishery interactions. University of Washington Institute of Forest Resource Contribution 57.

Center for Whale Research. 2017. Southern Resident Killer Whale Population. Center for Whale Research Website. Available at www.whaleresearch.com/orca-population. Accessed 6/20/2017.

Chamberlain, T. W., R. D. Harr, and F. H. Everest. 1991. Timber harvesting, silviculture and watershed processes. Pages 181-205 in W. R. Meehan (ed). Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19. 26 pp.

Chan, J. 2013. Email to Jim Muck (USFWS) regarding clarification of a 2004 pers. comm. Previously used regarding increase in bull trout abundance and foraging in marine waters. June 21, 2013.

Chapman, D.W. 1988. Critical-review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society 117(1):1-21.

City of Seattle. 2003. Seattle's Urban Blueprint for Habitat Protection and Restoration. City of Seattle's Salmon Team. Seattle, WA.

City of Seattle. 2013. 2012 Annual Report Combined Sewer Overflow (CSO) reduction program. Seattle Public Utilities. Protection Seattle's Waterways. Seattle, WA. March 30, 2013. Available at: http://www.seattle.gov/util/groups/public/@spu/@drainsew/documents/webcontent/01_026120.pdf.

City of Seattle. 2016. Elliott Bay Seawall Project Season 3 (2016) Acoustic Monitoring Report. May 31, 2016. The Greenbush Group, Inc. Seattle. WA. 76 pp.

Clark CW, W.T. Ellison, B.L. Southall, L. Hatch, S.M. Van Parijs, A. Frankel, and D. Ponirakis. 2009. Acoustic masking in marine ecosystems: intuitions, analysis, and implication. Mar Ecol Prog Ser 395:201-222.

Collins, M., R. Knutti, J. Arblaster, J. Dufresne, T. Fichefet, P. Friedlingstein, X. Gao, W.J. Gutowski Jr., T. Johns, G. Krinner, M. Shongwe, C. Tebaldi, A.J. Weaver, and M. Wehner. 2013. Long-term climate change: Projections, commitments and irreversibility. Pages 1029-1136 In T.F. Stocker, D. Qin, G.-. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley, eds. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY.

Combes, S. 2003. Protecting freshwater ecosystems in the face of global climate change. In: Hansen LJ et al. (eds) Buying time: a user's manual for building resistance and resilience to climate change in natural systems. WWF, Washington, UDA. Pp. 175-214. 44 pp.

Costello, A.B., T.E. Down, S.M. Pollard, C.J. Pacas, and E.B. Taylor. 2003. The influence of history and contemporary stream hydrology on the evolution of genetic diversity within species: an examination of microsatellite DNA variation in bull trout, *Salvelinus confluentus* (Pisces: Salmonidae). Evolution. 57(2):328-344. 17 pp.

Craig, S.D., and R.C. Wissmar. 1993. Habitat conditions influencing a remnant bull trout spawning population, Gold Creek, Washington (draft report). Fisheries Research Institute, University of Washington. Seattle, Washington. 47 pp.

Cullon, D.L., S. Jeffries, and P.S. Ross. 2001. An ecosystem approach to assessing the accumulation of persistent organic pollutants (POPs) in the food chain of harbor seals (Phoca vitulina) inhabiting the coastal waters of British Columbia and Washington. Puget Sound Research, poster group D: Toxic contaminants. Available at: http://www.psat.wa.gov/Publications/01_proceedings/sessions/abstract/abstr_d.pdf.

Curl, Jr., H.C., E.T. Baker, T.S. Bates, G.A. Gannon, R.A. Feely, T.L. Geiselman, M.F. Lamb, P.P. Murphy, D.J. Pashinski, A.J. Paulson, and D.A. Tennant. 1988. Contaminant transport from Elliott Bay and Commencement Bay. National Oceanic and Atmospheric Administration.

Curry, R.A., and W.S. MacNeill. 2004. Population-level responses to sediment during early life in brook trout. Journal of the North American Benthological Society 23:140-150.

Dambacher, J. M., M. W. Buktenica, and G. L. Larson. 1992. Distribution, abundance, and habitat utilization of bull trout and brook trout in Sun Creek, Crater Lake National Park, Oregon. Proceedings of the Gearhart Mountain Bull Trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis, Oregon.

Davidson, M. 2004. Transmission loss. University of Plymouth, Drake Circus, Plymouth, Devon, UK. Accessed May-25-2005.

DeHaan, P., M. Diggs, and J. VonBargen. 2011. Genetic analysis of bull trout in the Saint Mary River System. U.S. Fish and Wildlife Service. Abernathy Fish Technology Center, Longview, Washington.

DeLacy, A.C., B.S. Miller, S.F. Borton. 1972. Checklist of Puget Sound fishes. Wash. Sea Grant. Prog. 1-43.

Donald, D.B., and D.J. Alger. 1993. Geographic distribution, species displacement, and niche overlap for lake trout and bull trout in mountain lakes. Canadian Journal of Zoology 71:238-247.

Drake, J.M., and B.D. Griffen. 2010. Early warning signals of extinction in deteriorating environments. Nature, 467(7314):456-459.

Drake J. S., E. A. Berntson, J. M. Cope, R. G. Gustafson, E. E. Holmes, P. S. Levin, N. Tolimieri, R. S. Waples, S. M. Sogard, and G.D. Williams. 2010. Status of five species of rockfish in Puget Sound, Washington: Bocaccio (*Sebastes paucispinis*), Canary Rockfish (*Sebastes pinniger*), Yelloweye Rockfish (*Sebastes ruberrimus*), Greenstriped Rockfish (*Sebastes elongatus*) and Redstripe Rockfish (*Sebastes proriger*). U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-NWFSC-108, 234 pages.

Duffy, E., and D. Beauchamp. 2011. Rapid growth in the early marine period improves the marine survival of Chinook salmon (*Oncorhynchus tshawytscha*) in Puget Sound, Washington. Canadian Journal of Fisheries and Aquatic Sciences 68:232-240.

Duffy, E., D. Beauchamp, R. Sweeting, R. Beamish, and J. Brennan. 2010. Ontogenetic diet shifts of juvenile Chinook salmon in nearshore and offshore habitats of Puget Sound. Transactions of the American Fisheries Society 139(3):803–823.

Dunham, J., and B.E. Rieman. 1999. Metapopulation structure of bull trout: influence of physical, biotic, and geometrical landscape characteristics. Ecological Applications 9(2):642-655.

Dunham, J., B. Rieman, and G. Chandler. 2003. Influences of temperature and environmental variables on the distribution of bull trout within streams at the southern margin of its range. North American Journal of Fisheries Management 23:894-905.

Dunham, J., C. Baxter, K. Fausch, W. Fredenberg, S. Kitano, I. Koizumi, K. Morita, T. Nakamura, B. Rieman, K. Savvaitova, J. Stanford, E. Taylor, and S. Yamamoto. 2008. Evolution, ecology, and conservation of Dolly Varden, white-spotted char, and bull trout. Fisheries 33:537–550.

Ecology (Washington State Department of Ecology). 1995. Elliott Bay waterfront recontamination study Volume 2: Data Evaluation and remedial design recommendations report. Publication # 95-607. Prepared by the Washington State Department of Ecology, Elliott Bay/Duwamish Restoration Panel, Panel Publication 10. August.

Ebbesmeyer, C.C., Coomes, C.A., Cox, J.M., Crone, T.J., Kurrus, K.A., and Noah, E.C. 1998. Current structure in Elliott Bay, Washington: 1977-1996. Proceedings of the Puget Sound research conference, pp. 506–518.

Ecology (Washington State Department of Ecology). 2006. Washington State's Water Quality Assessment [303(d)]. Washington State Department of Ecology. Olympia, WA. http://www.ecy.wa.gov/programs/wq/303d/index.html.

Emmett, R.L., S.A. Hinton, S.L. Stone, and M.E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries, Vol. II: Species life history summaries. ELMR Rep. No. 8. NOAA/NOS SEA Division, Rockville, MD. 329 p.

Engås, A., S. Løkkeborg, E. Ona, and A. V. Soldal. 1996. Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). Canadian Journal of Fisheries and Aquatic Sciences 53:2238-2249.

Evans, M., K. Fazakas, J. Keating. 2009. Creosote Contamination in Sediments of the Grey Owl Marina in Prince Albert National Park, Saskatchewan, Canada. Water Air Soil Pollution. 201:161–184.

Feist, B.E., J.J. Anderson, and R. Miyamoto. 1992. Potential impacts of pile driving on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon behavior and distribution. FRI-UW-9603. Fisheries Resources Institute, University of Washington. Seattle, WA.

Fewtrell, J. L. 2003. The response of marine finfish and invertebrates to seismic survey noise. Ph.D. Thesis. Curtin University of Technology. Perth, Australia.

FHWA (Federal Highway Administration). 2010. Alaskan Way Viaduct Replacement Project 2010 Supplemental Draft Environmental Impact Statement. Submitted by Parsons Brinckerhoff Quade & Douglas, Inc. Prepared by Parametrix for Federal Highway Administration, Washington State Department of Transportation, and City of Seattle.

FHWG (Fisheries Habitat Working Group). 2008. Agreement in principle for interim criteria for injury to fish from pile driving activities. June 12, 2008.

Field, J. C. and S. Ralston. 2005. Spatial variability in rockfish (*Sebastes* spp.) recruitment events in the California Current System. Canadian Journal of Fisheries and Aquatic Sciences. Volume 62, pages 2199 to 2210.

Finneran, J.J., and C.E. Schlundt. 2010. Frequency-dependent and longitudinal changes in noise-induced hearing loss in a bottlenose dolphin (*Tursiops truncatus*). Journal of the Acoustical Society of America 128:567-570.

Finneran, J.J., C.E. Schlundt, D.A. Carder, J.A. Clark, J.A. Young, J.B. Gaspin, and S.H. Ridgway. 2000. Auditory and behavioral responses of bottlenose dolphins (*Tursiops truncatus*) and a beluga whale (*Delphinapterus leucas*) to impulsive sounds resembling distant signatures of underwater explosions. Journal of the Acoustical Society of America **108** (1):417-431.

Finneran, J.J., C.E. Schlundt, R. Dear, D.A. Carder, and S.H. Ridgway. 2002. Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. Journal of the Acoustical Society of America **111** (6):2929.

Finneran, J. J., R. Dear, D.A. Carder, and S.H. Ridgway. 2003. Auditory and behavioral responses of California sea lions (*Zalophus californianus*) to single underwater impulses from an arc-gap transducer. Journal of the Acoustical Society of America 114:1667-1677.

Finneran, J.J., D.A. Carder, C.E. Schlundt, and S.H. Ridgway. 2005. Temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*) exposed to mid-frequency tones. Journal of the Acoustical Society of America **118** (4):2696-2705.

Finneran, J.J., C.E. Schlundt, B. Branstetter, and R.L. Dear. 2007. Assessing temporary threshold shift in a bottlenose dolphin (*Tursiops truncatus*) using multiple simultaneous auditory evoked potentials. Journal of the Acoustical Society of America 122:1249–1264.

Finneran, J.J., D.A. Carder, C.E. Schlundt, and R.L. Dear. 2010a. Growth and recovery of temporary threshold shift at 3 kHz in bottlenose dolphins: Experimental data and mathematical models. Journal of the Acoustical Society of America 127:3256-3266.

Finneran, J.J., D.A. Carder, C.E. Schlundt, and R.L. Dear. 2010b. Temporary threshold shift in a bottlenose dolphin (*Tursiops truncatus*) exposed to intermittent tones. Journal of the Acoustical Society of America 127:3267-3272.

FishBase. 2010. Life-history of bocaccio. www.fishbase.org. Database accessed May 20, 2010.

Fishbase 2015. http://www.fishbase.org/Summary/SpeciesSummary.php?ID=2690&AT=bull+trout 2pp.

Fisher, R., S. M. Sogard, and S. A. Berkeley. 2007. Trade-offs between size and energy reserves reflect alternative strategies for optimizing larval survival potential in rockfish. Marine Ecology Progress Series. Volume 344, pages 257 to 270.

Foote, A.D., R.W. Osborne, and A.R. Hoelzel. 2004. Wahle-call response to masking boat noise. Nature 428:910.

Ford, M.J. (ed.). 2011. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC-113, 281 p.

Ford, J.K.B. and G.M. Ellis. 2006. Selective foraging by fish-eating killer whales *Orcinus orca* in British Columbia. Marine Ecology Progress Series 316:185-199.

Ford, M.J., M.B. Hanson, J.A. Hempelmann, K.L. Ayres, C.K. Emmons, G.S. Schorr, R.W. Baird, K.C. Balcomb, S.K. Wasser, K.M. Parsons, and K. Balcomb-Bartok. 2011. Inferred paternity and male reproductive success in a killer whale (Orcinus orca) population. Journal of Heredity 102: 537-553.

Fraley, J.J., and B.B. Shepard. 1989. Life history, ecology and population status of migratory bull trout (*Salvelinus confluentus*) in the Flathead lake and river system, Montana. Northwest Science 63(4):133-143.

Fresh, K. 2006. Juvenile Pacific salmon in Puget Sound. Technical Report 2006-06 Prepared in support of the Puget Sound Nearshore Partnership. 28pp. Available at: http://www.pugetsoundnearshore.org/technical_papers/pacjuv_salmon.pdf.

Frissell, C.A. 1999. An ecosystem approach to habitat conservation for bull trout: groundwater and surface water protection. Flathead Lake Biological Station, University of Montana, Open File Report Number 156-99, Polson, MT, January 07, 1999. 46 pp.

Furniss, M.J., T.D. Roelofs, and C.S. Yee. 1991. Road construction and maintenance. American Fisheries Society Special Publication 19:297-323. 14 pp.

Ganguly, A.R., K. Steinhaeuser, D.J. Erickson, M. Branstetter, E.S. Parish, N. Singh, J.B. Drake, and L. Buja. 2009. Higher trends but larger uncertainty and geographic variability in 21st century temperature and heat waves. Proceedings of the National Academy of Sciences 106(37):15555-15559.

Gaspin JB. 1975. Experimental investigations of the effects of underwater explosions on swimbladder fish, 1: 1973 Chesapeake Bay Tests. Silver Springs, Maryland: Naval Surface Weapons Center Silver - White Oak Laboratory. 76 p.

Gaspin, J.B., M.L. Wiley, and G.B. Wiley. 1976. Experimental investigations of the effects of underwater explosions on swimbladder fish, II: 1975 Chesapeake Bay tests. NSWC/WOL/TR 76-61. White Oak Laboratory, Naval Surface Weapons Center, Silver Spring, Maryland, 65pp.

Gilbert C. H. 1897. The fishes of the Klamath Basin. Bulletin of the U.S. Fish Commission 17:1-13.

Gisiner, R.C., E. Cudahy, G.V. Frisk, R. Gentry, R. Hofman, A.N. Popper. and J.W. Richardson. 1998. Workshop on the Effects of Anthropogenic Noise in the Marine Environment. In: Gisiner, R.C., ed. Effects of Anthropogenic Noise in the Marine Environment. February 10-12, 1998. Marine Mammal Science Program, Office of Naval Research. 141 pp.

Glick, P., B.A. Stein, and N.A. Edelson. 2011. Scanning the conservation horizon: a guide to climate change vulnerability assessment. National Wildlife Federation, Washington, D.C., 2011. 168 pp.

Goetz, F. 1989. Biology of the bull trout, *Salvelinus confluentus*, a literature review. Willamette National Forest, Eugene, Oregon. 53 pp.

Goetz, F. 1994. Distribution and juvenile ecology of bull trout (*Salvelinus confluentus*) in the Cascade Mountains. M.S. thesis. Oregon State University, Corvallis. 190 pp.

Goetz, F. 2003. U.S. Army Corps of Engineers. Unpublished ultrasonic telemetry data from the Snohomish River basin and Puget Sound.

Goetz, F., E. Connor, E. Jeanes, and M. Hayes. 2012. Migratory Patterns and Habitat Use of Bull Trout in the Puget Sound. Presentation at the Salvelinus Confluentus Curiosity Conference, Lake Crescent, WA. August 15-17, 2012.

Goetz, F., E.D. Jeanes, and E.M. Beamer. 2004. Bull trout in the nearshore. U.S. Army Corps of Engineers, Preliminary draft, Seattle, Washington, June 2004. 396 pp.

Govoni, J.J., M.A. West, and L.R. Settle. 2008. Effects of underwater explosions on larval fish: implications for a coastal engineering project. Journal of Coastal Research 24:228-233.

Greene, C. and A. Godersky. 2012. Larval Rockfish in Puget Sound surface waters. Northwest Science Center. Seattle, WA. December 27, 2012.

Groot, C. and L. Margolis. 1991. Pacific salmon life histories. UBC Press, Vancouver, British Columbia, Canada: 564 pages.

Haas, G. R., and J. D. McPhail. 1991. Systematics and distributions of Dolly Varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*) in North America. Can. J. Fish. Aquat. Sci. 48: 2191-2211. 21 pp.

Halderson, L. and L. J. Richards. 1987. Habitat use and young of the year copper rockfish (*Sebastes caurinus*) in British Columbia. Pages 129 to 141 *in* Proceedings International Rockfish Symposium, Anchorage, Alaska, Alaska Sea Grant Rep. 87-2, Fairbanks, Alaska 99701.

Hamilton, M. 2008. Evaluation of management systems for KS^n fisheries and potential management application to British Columbia's inshore rockfish fishery. Simon Fraser University.

Hannah, R. W., and K. M. Matteson. 2007. Behavior of nine species of Pacific rockfish after hook and line capture, recompression, and release. Transactions of the American Fisheries Society. Volume 136, pages 24 to 33.

Hanson, B., C. Emmons, M. Sears, K. Ayres. 2010. Prey selection by southern resident killer whales in inland waters of Washington during the fall and early winter. Unpublished Report. Draft 30 October 2010.

Hard, J. 1995. A quantitative genetic perspective on the conservation of intraspecific diversity. American Fisheries Society Symposium 17:304-326.

Hari, R. E., D. M. Livingstone, R. Siber, P. Burkhardt-Holm, and H. Guttinger. 2006. Consequences of climatic change for water temperature and brown trout populations in alpine rivers and streams. Global Change Biology 12:10–26. 17 pp.

Harris, G. P. 1986. Phytoplankton ecology, structure, function, and fluctuation. Chapman and Hall, London.

Hartill, T. and S. Jacobs. 2007. Distribution and abundance of bull trout in the Sprague River (Upper Klamath Basin), 2006. Oregon Department of Fish and Wildlife. Corvallis, Oregon.

Hartt, A.C., and M.B. Dell. 1986. Early oceanic migrations and growth of juvenile Pacific salmon and steelhead trout. Int. N. Pac. Fish. Comm. Bull. 46:1-105.

Harvey, C. J. 2005. Effects of El Niño events on energy demand and egg production of rockfish (Scorpaenidae: *Sebastes*): a bioenergetics approach. Fishery Bulletin. Volume 103, pages 71 to 83.

Hastings, M.C. 1990. Effects of Underwater Sound on Fish. Document No. 46254-900206-01IM, Project No. 401775-1600, AT&T Bell Laboratories.

Hastings, M.C. 2002. Clarification of the meaning of sound pressure levels and the known effects of sound on fish. Ohio State University, Columbus, OH. August 26, 2002. 6 pp.

Hastings, M.C. 2007. Pers. comm. Calculation of SEL for Govoni el al (2003,2007) and Popper et al. (2007) studies. Report for Amendment to Project 15218, J&S Working Group. Applied Research Lab. Penn State University. 12-14-2007.

Hastings, M.C., and A.N. Popper. 2005. Effects of sound on fish. California Department of Transportation, , Report Contract No. 43A0139, Task Order, 1, Sacramento, CA. January 28, 2005. 82 pp.

Hastings, M.C., A.N. Popper, J.J. Finneran, and P. Lanford. 1996. Effects of low-frequency underwater sound on hair cells of the inner ear and lateral line of the teleost fish *Astronotus ocellatus*. Journal of the Acoustical Society of America 99(3):1759-66.

Hawkins, A.D. and A.D.F. Johnstone. 1978. The hearing of the Atlantic salmon, *Salmo salar*. Journal of Fish Biology 13:655-673.

Hayden-Spear, J. 2006. Nearshore habitat associations of young-of-year copper (*Sebastes caurinus*) and quillback (*S. maliger*) rockfish in the San Juan Channel, Washington. Master of Science Dissertation, University of Washington, Seattle, WA. 38 pages.

Healey, M.C., and A. Prince. 1995. Scales of variation in life history tactics of Pacific salmon and the conservation of phenotype and genotype. American Fisheries Society Symposium 17:176-184.

Henjum, M.G., J.R. Karr, D.L. Bottom, D.A. Perry, J.C. Bednarz, S.G. Wright, S.A. Beckwitt, and E. Beckwitt. 1994. Interim protection for late-successional forests, fisheries, and watersheds. National forests east of the Cascade Crest, Oregon, and Washington. A report to the Congress and President of the United States Eastside Forests Scientific Society Panel. American Fisheries Society, American Ornithologists Union Incorporated, The Ecological Society of America, Society for Conservation Biology, The Wildlife Society. The Wildlife Society Technical Review 94-2. 112 pp.

Higgins, K., P. Schlenger, J. Small, D. Hennessy, J. Hall. 2005. Spatial relationships between beneficial and detrimental nearshore habitat parameters in WRIA 9 and the city of Seattle. Proceedings of the 2005 Puget Sound Georgia Basin Research Conference. Available at: http://deckard.engr.washington.edu/epp/psgb/2005psgb/2005proceedings/Papers/B7_HIGGI.pdf.

Hilborn, R., T.P. Quinn, D.E. Schindler, and D.E. Rogers. 2003. Biocomplexity and fisheries sustainability. Proceedings of the National Academy of Sciences 100:6564-6568.

Hoelscher, B., and T.C. Bjornn. 1989. Habitat, density, and potential production of trout and char in Pend Oreille Lake tributaries. Idaho Department of Fish and Game, Project F-710R-10, Subproject III, Job No. 8., Boise, Idaho, January 1989. 60 pp.

Holt, M.M. 2008. Sound exposure and Southern Resident killer whales (Orcinus orca): A review of current knowledge and data gaps. NOAA Technical Memorandum NMFS-NWFSC-89, U.S. Department of Commerce, Seattle, Washington.

Holt, M.M., D.P. Noren, V. Veirs, C.K. Emmons, and S. Veirs. 2009. Speaking up: Killer whales (*Orcinus orca*) increase their call amplitude in response to vessel noise. Journal of the Acoustical Society of America 125:EL27-EL31.

Howell, P.J., and D.V. Buchanan. 1992. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis, Oregon. 67 pp.

Howell, P. J., J. B. Dunham, and P. M. Sankovich. 2009. Relationships between water temperatures and upstream migration, cold water refuge use, and spawning of adult bull trout from the Lostine River, Oregon, USA. Published in 2009: Ecology of Freshwater Fish 2010:19: 96-106. Malaysia. 11 pp.

Huber, M., and R. Knutti. 2011. Anthropogenic and natural warming inferred from changes in Earth's energy balance. Nature Geoscience 5(1):31-36.

Hudson, J. M., R. Koch, J. Johnson, J. Harris, M. L. Koski, B. Galloway, and J. D. Williamson. 2015. Clackamas River Bull Trout Reintroduction Project, 2014 Annual Report. Oregon Department of Fish and Wildlife and U.S. Fish and Wildlife Service, 33 pp.

IDFG (Idaho Department of Fish and Game). 2005. Bull trout status review and assessment in the State of Idaho. Grant #F-73-R-27. Idaho Department of Fish and Game. 57pp.

IDFG (Idaho Department of Fish and Game). 2008. Distribution, abundance, and population trends of bull trout in Idaho. North American Journal of Fisheries Management 28:1687-1701.

IDFG (Idaho Department of Fish and Game). 2014. Bull trout trends in abundance and probabilities of persistence in Idaho. North American Journal of Fisheries Management. 34:1, 202-214.

IPCC. 2007a. Summary for policymakers. pp 1-18 In: Climate Change 2007: The physical science basis. Contribution of working group I to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, New York, 2007. 582 pp.

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate change 2007: Synthesis report. Contribution of working groups I, II and III to the fourth assessment report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change;, Geneva, Switzerland, 2007. 52 pp.

IPCC. 2014a. Climate change 2014: Impacts, adaptation, and vulnerability part A: Global and sectoral aspects, contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK. 1150 pp.

IPCC. 2014b. Climate change 2014: Synthesis report, contribution of working groups I, II, and III to the fifth assessment report of the intergovernmental panel on climate change. Intergovernmental Panel on Climate Change, Geneva, Switzerland. 151 pp.

ISAB (Independent Scientific Advisory Board). 2007. Climate change impacts on Columbia River basin fish and wildlife. Northwest Power and Conservation Council, Portland, Oregon. http://www.nwcouncil.org/library/isab/ISAB%202007-2%20Climate%20Change.pdf.

Jarvis, E.T. and C.G. Lowe. 2008. The effects of barotrauma on the catch-and-release survival of southern California nearshore and shelf rockfish (Scorpaenidae, *Sebastes* spp.). Canadian Journal of Aquatic and Fishery Sciences. Volume 65, pages 1286 to 1296.

Johnson, L. 1990. State of Nevada, Department of Wildlife, Bull trout management plan. State of Nevada statewide Fisheries Program, project number F-20-26, Job number 2017.4. 17 pp.

Johnson, L.L., M.R. Arkoosh, C.F. Bravo, T.K. Collier, M.M. Krahn, J.P. Meador, M.S. Myers, W.L. Reichert, and J.E. Stein. 2008. The effects of polycyclic aromatic hydrocarbons in fish from Puget Sound, Washington. *In* The Toxicology of Fishes. Di Giulio, R.T., and D.E. Hinton. CRC Press, Boca Raton, Florida.

Karrow, N., H.J. Boermans, D.G Dixon, A. Hontella, K.R. Solomon, J.J. Whyte, and N.C. Bols. 1999. Characterizing the immunotoxicity of creosote to rainbow trout (*Oncorhynchus mykiss*): a microcosm study. Aquatic Toxicology, 45:223–239.

Kastelein R., and N. Jennings. 2012. Impacts of Anthropogenic Sounds on *Phocoena phocoena* (Harbor Porpoise). In: Popper A.N., Hawkins A. (eds) The Effects of Noise on Aquatic Life. Advances in Experimental Medicine and Biology, vol 730. Springer, New York, NY.

Kastelein, R.A., R. Gransier, L. Hoek, A. Macleod, and J.M. Terhune. 2012a. Hearing threshold shifts and recovery in harbor seals (*Phoca vitulina*) after octave-band noise exposure at 4 kHz. Journal of the Acoustical Society of America 132:2745-2761.

KCEL (King County Environmental Laboratory). 1998. King County environmental laboratory quality assurance review for Duwamish Estuary/Elliott Bay squid tissue study RWSP water quality assessment. Available at: ftp://dnr.metrokc.gov/wlr/maa/squidqa.doc.

Kerwin, J. and T. S. Nelson. 2000. Habitat Limiting Factors and Reconnaissance Assessment Report, Green/Duwamish and Central Puget Sound Watersheds (WRIA 9 and Vashon Island). Washington Conservation Commission and King County Department of Natural Resources. Seattle, WA.

King County (King County Department of Natural Resources and Parks). 2009. Water Quality Status Report for Marine Waters 2005–2007. Prepared by K. Stark, S. Mickelson, and S. Keever. King County (King County Department of Transportation), Marine Division. 2010. Biological Assessment: King County Marine Division, Passenger Ferry Moorage and Maintenance Barge Project. Prepared by Anchor QEA. September 2010.

King County. 2016. King County Transportation Water Taxi website for downtown Seattle routes to Vashon Island and West Seattle. Available at http://www.kingcounty.gov/transportation/kcdot/WaterTaxi.aspx. Accessed November 28, 2016.

Kirtman, B., S.B. Power, A.J. Adedoyin, G.J. Boer, R. Bojariu, I. Camilloni, F. Doblas-Reyes, A.M. Fiore, M. Kimoto, G. Meehl, M. Prather, A. Sarr, C. Schär, R. Sutton, G.J. van Oldenborgh, G. Vecchi, and H. Wang. 2013. Near-term climate change: Projections and predictability. Pages 953-1028 In T.F. Stocker, D. Qin, G.-. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley, eds. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY.

Knudsen, F.R., C.B. Schreck, S.M. Knapp, P.S. Enger, and O. Sand. 1997. Infrasound produces flight and avoidance responses in Pacific juvenile salmonids. Journal of Fish Biology 51:824-829.

Kraemer, C. 1994. Some observations on the life history and behavior of the native char, Dolly Varden (*Salvelinus malma*) and bull trout (*Salvelinus confluentus*) of the North Puget Sound Region. Wash. Deptartment of Wildlife. Draft.

Krahn, M.M., M.J. Ford, W.F. Perrin, P.R. Wade, R.B. Angliss, M.B. Hanson, B.L. Taylor, G.M. Ylitalo, M.E. Dahlheim, J.E. Stein, and R.S. Waples. 2004. 2004 status review of Southern Resident killer whales (*Orincus orca*) under the Endangered Species Act, U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-62, 73p.

Kraig, E. 2012. State of Washington, Washington State Sport Catch Report 2008. Washington Department of Fish and Wildlife. Fish Program, Science Division. Olympia, WA July 2012. 93 pp.

Kraig, E. 2013. State of Washington, Washington State Sport Catch Report 2009. Washington Department of Fish and Wildlife. Fish Program, Science Division. Olympia, WA January 2013. 94 pp.

Lambourn, D. M., S. J. Jeffries, and J. P. Dubey. 2001. Seroprevalence of Toxoplasma gondii in harbor seals (Phoca vitulina) in Southern Puget Sound, Washington. The Journal of Parasitology. 87(5). Available at: http://wdfw.wa.gov/wlm/research/papers/harbor_seals/harbor_seals.pdf.

Lance, M.M., and S.F. Pearson. 2016. 2015 Washington at-sea marbled murrelet population monitoring: Research progress report. Washington Department of Fish and Wildlife, Wildlife Program, Science Division, Olympia, WA, January 2016. 23 pp.

Landahl, J. T., L. L. Johnson, J. E. Stein, T. K. Collier, and U. Varanasi. 1997. Approaches for Determining Effects of Pollution on Fish Populations of Puget Sound. Transactions of the American Fisheries Society. Volume 126, pages 519 to 535.

Landrum, P.F., B.J. Eadie, W.R. Faust, N.R. Morehead, and M.J. McCormick. 1984. Role of sediment in t e bioaccumulation of benzo(a)pyrene by the amphipod, *Pontoporeia hoyi.* Pages 799-812 *in* M. Cooke and A.J. Dennis (editors). Polynuclear aromatic hydrocarbons: mechanisms, methods and metabolism. Battelle Press, Columbus, Ohio.

Landrum, P.F., and D. Scavia. 1983. Influence of sediment on anthracene uptake, depuration, and biotransformation by the amphipod *Hyalella azteca.* Canadian Journal of Fishery and Aquatic Sciences, 40:298-305.

Laughlin, J. 2006. Ambient Underwater Sound Measurements in Elliott Bay, March 21, 2006. Washington State Department of Transportation, Seattle, Washington, 4 pp.

Laughlin, J. 2011. Seattle Ferry Terminal Background Sound Measurement Results, April 2011. Washington State Department of Transportation Technical Memorandum to R. Huey, R. Wilson, and T. Castor. May 18, 2011.

Laughlin, J. 2015. Compendium of Background Sound Levels for Ferry Terminals in Puget Sound. WSF Underwater Background Monitoring Project. Washington State Department of Transportation, Seattle, Washington, May 2015. 60 pp.

Leary, R.F., and F.W. Allendorf. 1997. Genetic confirmation of sympatric bull trout and Dolly Varden in western Washington. Transactions of the American Fisheries Society 126:715-720.

Leary, R.F., F.W. Allendorf, and S.H. Forbes. 1993. Conservation genetics of bull trout in the Columbia and Klamath River drainages. Conservation Biology 7(4):856-865.

Leathe, S.A., and P.J. Graham. 1982. Flathead Lake fish food habits study. US EPA, Region VIII, Water Division, Contract R008224-01-4, Denver, Colorado, October, 1982. 209 pp.

Lee, R., and G. Dobbs. 1972. Uptake, Metabolism and Discharge of Polycyclic Aromatic Hydrocarbons by Marine Fish. Marine Biology. 17:201-208.

Light, J., L. Herger, and M. Robinson. 1996. Upper Klamath basin bull trout conservation strategy, a conceptual framework for recovery. Part one. The Klamath Basin Bull Trout Working Group. 88 pp.

Love, M. S., M. Carr, and L. Haldorson. 1991. The ecology of substrate-associated juveniles of the genus *Sebastes*. Environmental Biology of Fish. Volume 30, pages 225 to 243.

Love, M.S., M. M. Yoklavich, and L. Thorsteinson. 2002. The rockfishes of the Northeast Pacific. University of California Press, Berkeley, California. 403 pages.

Love, M. S. 2011. Certainly More Than You Want to Know About the Fishes of the Pacific Coast. Santa Barbara, CA, Really Big Press.

Lucke, K., U. Siebert, P.A. Lepper, and M. Blanchet. 2009. Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli. Journal of the Acoustical Society of America **125** (6):4060.

Lynch, D., G. Falxa, J. Baldwin, M.M. Lance, S.K. Nelson, S.F. Pearson, M.G. Raphael, C. Strong, and R. Young. 2016. Marbled murrelet effectiveness monitoring, Northwest Forest Plan: 2015 summary report. 19 pp.

Magnuson, J.J., Robertson, D.M., Benson, B.J., Wynne, R.H., Livingstone, D.M., Arai, T., Assel, R.A., Barry, R.G., Card, V., Kuusisto, E., Granin, N.G., Prowse, T.D., Stewart, K.M., and Vuglinski, V.S. 2000. Historical trends in lake and river cover in the Northern Hemisphere. Science 289:1743-1746. 5 pp.

Mantua, N., I. Tohver, and A. F. Hamlet. 2009. Impacts of climate change on key aspects of freshwater salmon habitat in Washington State. In: Washington Climate Change Impacts Assessment: Evaluating Washington's future in a changing climate. Climate Impacts Group, University of Washington, Seattle, Washington. http://cses.washington.edu/db/pdf/wacciach6salmon649.pdf.

Martinez, P. J., P. E. Bigelow, M. A. Deleray, W. A. Fredenberg, B. S. Hansen, N. J. Horner, S. K. Lehr, R. W. Schneidervin, S. A. Tolentino, and A. E. Viola. 2009. Western lake trout woes. Fisheries 34:424-442.

Matsuda, R.I., G.W. Isaac, and R.D. Dalseg. 1968. Fishes of the Green-Duwamish River. Water Quality Series No. 4, Municipality of Metropolitan Seattle, Seattle, Washington. 38 pp.

Matthews, K. R. 1989. A comparative study of habitat use by young-of-the year, subadult, and adult rockfishes on four habitat types in Central Puget Sound. Fishery Bulletin, U.S. Volume 88, pages 223 to 239.

MBTSG (Montana Bull Trout Scientific Group). 1995a. Upper Clark Fork River drainage bull trout status report (including Rock Creek). Prepared for Montana Bull Trout Restoration Team. Helena, Montana. 46 pp.

MBTSG (Montana Bull Trout Scientific Group). 1995b. Bitterroot River drainage bull trout status report. Prepared for Montana Bull Trout Restoration Team. Helena, Montana. 34 pp.

MBTSG (Montana Bull Trout Scientific Group). 1995c. Blackfoot River drainage bull trout status report. Prepared for Montana Bull Trout Restoration Team. Helena, Montana. 43 pp.

MBTSG (Montana Bull Trout Scientific Group). 1995d. Flathead River drainage bull trout status report (including Flathead Lake, the North and Middle forks of the Flathead River and the Stillwater and Whitefish River). Prepared for Montana Bull Trout Restoration Team. Helena, Montana. 52 pp.

MBTSG (Montana Bull Trout Scientific Group). 1995e. South Fork Flathead River drainage bull trout status report (upstream of Hungry Horse Dam). Prepared for Montana Bull Trout Restoration Team. Helena, Montana. 43 pp.

MBTSG (Montana Bull Trout Scientific Group). 1996a. Swan River drainage bull trout status report (including Swan Lake). Prepared for Montana Bull Trout Restoration Team. Helena, Montana. 48 pp.

MBTSG (Montana Bull Trout Scientific Group). 1996b. Lower Clark Fork River drainage bull trout status report (Cabinet Gorge Dam to Thompson Falls). Prepared for Montana Bull Trout Restoration Team. Helena, Montana. 43 pp.

MBTSG (Montana Bull Trout Scientific Group). 1996c. Middle Clark Fork River drainage bull trout status report (from Thompson Falls to Milltown, including the lower Flathead River to Kerr Dam). Prepared for Montana Bull Trout Restoration Team. Helena, Montana. 31 pp.

MBTSG (Montana Bull Trout Scientific Group). 1996d. Lower Kootenai River drainage bull trout status report (below Kootenai Falls). Prepared for Montana Bull Trout Restoration Team. Helena, Montana. 39 pp.

MBTSG (Montana Bull Trout Scientific Group). 1996e. Middle Kootenai River drainage bull trout status report (between Kootenai Falls and Libby Dam). Prepared for Montana Bull Trout Restoration Team. Helena, Montana. 27 pp.

MBTSG (Montana Bull Trout Scientific Group). 1996f. Upper Kootenai River drainage bull trout status report (including Lake Koocanusa, upstream of Libby Dam). Prepared for Montana Bull Trout Restoration Team. Helena, Montana. 31 pp.

MBTSG. 1998. The relationship between land management activities and habitat requirements of bull trout. Montana Fish, Wildlife, and Parks, Helena, MT, May 1998. 77 pp.

McCain, B., D. Malins, M. Krahn, D. Brown, W. Gronlund, L. Moore, and S-L. Chan. 1990. Uptake of Aromatic and Chlorinated Hydrocarbons by Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) in an Urban Estuary. Archives of Environmental Contamination and Toxicology, 19:10-16.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe. 2000. Marine Seismic Surveys – A Study of Environmental Implications. APPEA Journal: 693-708.

Meador, J., F. Sommers, G. Ylitalo, and C. Sloan. 2006. Altered growth and related physiological responses in juvenile Chinook salmon (*Oncorhynchus tshawytscha*) from dietary exposure to polycyclic aromatic hydrocarbons (PAHs). Canadian Journal of Fishery and Aquatic Sciences, 63: 2364–2376.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T. Wainwright, and E. Bjorkstedt. 2000. Viable Salmon Populations and the Recovery of Evolutionarily Significant Units. National Marine Fisheries Service, Northwest Fisheries Science Center, NOAA Technical Memo, NMFS-NWFSC-42. 156 p. http://www.nwfsc.noaa.gov/publications/techmemos/tm42/tm42.pdf.

McIntosh, B.A., J.R. Sedell, J.E. Smith, R.C. Wissmar, S.E. Clarke, G.H. Reeves, and L.A. Brown. 1994. Management history of eastside ecosystems: Changes in fish habitat over 50 years, 1935 to 1992. U.S. Forest Service, Pacific Northwest Research Station, General Technical Report. PNW-GTR 321. 62 pp.

McPhail, J.D., and J.S. Baxter. 1996. A review of bull trout (*Salvelinus confluentus*) life-history and habitat use in relation to compensation and improvement opportunities. Department of Zoology, University of British Columbia, Fisheries Management Report Number 104, Vancouver, BC. 31 pp.

Meehan, W.R. 1991. Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society Special Publication 19. 12 pp.

Meehl, G., T. Stocker, W. Collins, P. Friedlingstein, A. Gaye, J. Gregory, A. Kitoh, R. Knutti, J. Murphy, A. Noda, S. Raper, I. Watterson, A. Weaver, and Z. Zhao. 2007. Global Climate Projections. Pages 747-845 In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller, eds. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Meeuwig, M., C. S. Guy, S. T. Kalinowski, and W. Fredenberg. 2010. Landscape influences on genetic differentiation among bull trout populations in a stream-lake network. Molecular Ecology 19:3620-3633.

Meffe, G.K., and C.R. Carroll. 1994. Principles of conservation biology. Sinauer Associates, Inc. Sunderland, Massachusetts. 8 pp.

Methot, R. and I.J. Stewart. 2005. Status of U.S. canary rockfish resource in 2005. Pacific Fishery Management Council, Portland, Oregon.

Miller, B. S. and S. F. Borton. 1980. Geographical distribution of Puget Sound fishes: Maps and data source sheets. University of Washington Fisheries Research Institute, 3 volumes.

Minckley, W. L., D. A. Henrickson, and C. E. Bond. 1986. Geography of western North American freshwater fishes: description and relationships to intracontinental tectonism. Pages 519-613 *in* C. H. Hocutt and E. O. Wiley, editors. The zoogeography of North American freshwater fishes. Wiley and Sons, New York.

MISM (Puget Sound Marine Invasive Species Volunteer Monitoring Program). 2009. Marine Invasive Species Identification Guide for the Puget Sound Area. Sponsored by the Washington Department of Fish and Wildlife and the Puget Sound Partnership. Publication No. PSP09-02, June.

Mogen, J. 2013. Bull trout investigations in the Saint Mary River Drainage, Montana – 2010-2012 summary report. U.S. Fish and Wildlife Service Northern Rockies FWCO, Bozeman, Montana.

Mogen, J. T., and L. R. Kaeding. 2001. Population biology of bull trout (*Salvelinus confluentus*) in the Saint Mary River drainage, progress report 1997-2001. U.S. Fish and Wildlife Service, Bozeman, Montana.

Mogen, J. T., and L. R. Kaeding. 2005a. Identification and characterization of migratory and nonmigratory bull trout populations in the St. Mary River drainage, Montana. Transactions of the American Fisheries Society 134:841-852.

Mogen, J. T., and L.R. Kaeding. 2005b. Large-scale, seasonal movements of radiotagged, adult bull trout in the St. Mary River drainage, Montana and Alberta. Northwest Science 79(4):246-253.

Mooney, T.A., P.E. Nachtigall, and S. Vlachos. 2009a. Sonar-induced temporary hearing loss in dolphins. Biology Letters 5:565-567.

Mooney, T.A., P.E. Nachtigall, M. Breese, S. Vlachos, and W.W.L. Au. 2009b. Predicting temporary threshold shifts in a bottlenose dolphin (Tursiops truncatus): The effects of noise level and duration. Journal of the Acoustical Society of America 125:1816-1826.

Moore, T. 2006. Distribution and abundance of bull trout and redband trout in Leonard and Deming Creeks, July and August, 2005. Oregon Department of Fish and Wildlife. Corvallis, Oregon.

Morfey, C.L. 2001. Dictionary of acoustics. Pages 347-347 p. In Dictionary of acoustics, Academic Press, San Diego.

Moser, H. G., R. L. Charter, W. Watson, D. A. Ambrose, J. L. Butler, J. Charter, and E. M. Sandknop. 2000. Abundance and distribution of rockfish (*Sebastes*) larvae in the southern California Bight in relation to environmental conditions and fishery exploitation. California Cooperative Oceanic Fisheries Investigations Report. Volume 41, pages 132 to 147.

Mote, P. W. and E. P. Salathé. 2009. Future climate in the Pacific Northwest. In: Washington Climate Change Impacts Assessment: Evaluating Washington's future in a changing climate. Climate Impacts Group, University of Washington, Seattle, Washington. http://www.cses.washington.edu/db/pdf/wacciach1scenarios642.pdf.

Moulton, L.L. and B.S. Miller. 1987. Characterization of Puget Sound marine fishes: survey of available data. Fisheries Research Institute, School of Fisheries, University of Washington. FRI-UW 8716.

Mueller, R.P., D.A. Neitzel, W.V. Mavros, and T.J. Carlson. 1998. Evaluation of low and high frequency sound for enhancing fish screening facilities to protect outmigrating salmonids. U.S. Department of Energy, Bonneville Power Administration, Project Number 86-118. Portland, OR. 26p

Myrick, C.A., F.T. Barrow, J. Dunham, B.L. Gamett, G.R. Haas, J.T. Peterson, B. Rieman, L.A. Weber, and A.V. Zale. 2002. Bull trout temperature thresholds: peer review summary. U.S. Fish and Wildlife Service, Lacey, Washington, September 19, 2002. 13 pp.

Nachtigall, P.E., J.L. Pawloski, and W.W. L. Au. 2003. Temporary threshold shifts and recovery 32 following noise exposure in the Atlantic bottlenose dolphin (Tursiops truncatus). Journal 33 of the Acoustical Society of America 113:3425-3429.

Nachtigall, P.E., A. Ya. Supin, J.L. Pawloski, and W.W.L. Au. 2004. Temporary threshold shifts 36 after noise exposure in the bottlenose dolphin (Tursiops truncatus) measured using 37 auditory evoked potentials. Marine Mammal Science 20:673-687.

Nedwell, J., and B. Edwards. 2002. Measurements of underwater noise in the Arun River during piling at County Wharf, Littlehampton. Subacoustech Ltd, Report No. 513 R 0108, Hampshire, UK, August 01, 2002. 25 pp.

Neff, J.M. 1982. Accumulation and release of polycyclic aromatic hydrocarbons from water, food, and sediment by marine animals. Pages 282-320 *in* N.L. Richards and B.L. Jackson (editors.). Symposium: carcinogenic polynuclear aromatic hydrocarbons n the marine environment. U.S. Environmental Protection Agency, Report 600/9-82-013.

Neff, J., B. Cox, D. Dixit, and J. Anderson. 1976. Accumulation and Release of Petroleum Derived Aromatic Hydrocarbons by Four Species of Marine Animals. Marine Biology. 38, 279-289.

Nehlsen, W., J. Williams, and J. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(02):4-21. 20 pp.

Nelson, T. 2013. Elliott Bay. Tom Nelson's Salmon University, Your complete saltwater fish resource. Available at: http://www.salmonuniversity.com/psn_elliott_bay.html.

Nelson, T. S., G. Ruggerone, H. Kim, R. Schaefer and M. Boles. 2004. Juvenile Chinook Migration, Growth and Habitat Use in the Lower Green River, Duwamish River and Nearshore of Elliott Bay 2001-2003, Draft Report. King County Department of Natural Resources and Parks. Seattle, Washington. 133 p + appendices.

Newcombe, C.P., and D.D. MacDonald. 1991. Effects of Suspended Sediments on Aquatic Ecosystems. North American Journal of Fisheries Management 11(1):72-82.

Newton, J.A., and S. Pribyl. 1994. Bull trout population summary: Lower Deschutes River subbasin. Oregon Department of Fish and Wildlife, The Dalles, Oregon. Oregon administrative rules, proposed amendments to OAR 340-41-685 and OAR 340-41-026. January 11, 1996. 18 pp.

Nichol, D. G. and E. K. Pikitch. 1994. Reproduction of darkblotched rockfish off the Oregon coast. Transactions of the American Fisheries Society. Volume 123, No. 4, pages 469 to 481.

Nightingale, B., and C.A. Simenstad. 2001a. Overwater structures: marine issues. White Paper, Res. Proj. T1803, Task 35, Wash. State Dept. Transportation, Washington State Trans. Center (TRAC), Seattle, WA. 133 pp + appendices.

NMFS (National Marine Fisheries Service). 1991. Recovery Plan for the Humpback Whale (*Megaptera novaeangliae*). Prepared by the Humpback Whale Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland, 105 pp.

NMFS. 1993. Sampling and Analytical Methods of the National Status and Trends Program, National Benthic Surveillance and Mussel Watch Projects 1984–1992. NOAA Technical Evaluation of Field Bioaccumulation as a Monitoring Tool Memorandum NOS ORCA 71, NOAA, Silver Springs, Maryland.

NMFS. 2003. Marine Protected Areas and the Early Life History of Fishes. AFSC Processed Report 2003-10. Seattle, WA. September 2003. 36 pp.

NMFS. 2008. Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*). Prepared by the National Marine Fisheries Service, Northwest Region. January 17, 2008.

NMFS. 2011. 2011 Implementation Status Assessment –Final Report. A Qualitative Assessment of Implementation of the Puget Sound Chinook Salmon Recovery Plan. Prepared by: Millie M. Judge, Lighthouse Natural Resource Consulting, Inc. for NMFS, NWR. Portland, Oregon. 45 p

NMFS. 2011b. 5-year review: summary and evaluation of Puget Sound Chinook, Hood Canal summer chum, and Puget Sound steelhead. National Marine Fisheries Service, Portland, Oregon.

NMFS. 2016a. 2016 5-Year Review: Summary & Evaluation of Puget Sound Chinook Salmon, Hood Canal Summer-run Chum Salmon, and Puget Sound Steelhead. National Marine Fisheries Service, West Coast Region, Portland, OR. Available at http://www.westcoast.fisheries.noaa.gov/publications/status_reviews/salmon_steelhead/2016/2016_5-yr_ps.pdf.

NMFS. 2016b. Draft Rockfish Recovery Plan: Puget Sound/Georgia Basin yelloweye rockfish (*Sebastes ruberrimus*) and bocaccio (*Sebastes paucispinis*). National Marine Fisheries Service. Seattle, Washington.

NMFS. 2016c. Yelloweye rockfish (*Sebastes ruberrimus*), canary rockfish (*Sebastes pinneger*), and bocaccio (*ebastes paucispinis*) of the Puget Sound/Georgia Basin. 5-year Review: Summary and Evaluation. NOAA's National Marine Fisheries Service, West Coast Region, Seattle WA.

NMFS. 2016d. October 21, 2016 Memorandum from Donna Wieting, Director, Office of Protected Resources, to Regional Administrators on Internal Guidance on the Endangered Species Act Term "Harass."

NOAA (National Oceanic and Atmospheric Administration). 2011. Datums published by NOAA at Station 9447130, Epoch 1983 to 2001, retrieved March 28, 2011 from http://tidesandcurrents.noaa.gov/benchmarks/9447130.html#DatumsPage.

NOAA Fisheries. 2017. 2016 West Coast Entanglement Summary. March 2017. 7 pp. http://www.westcoast.fisheries.noaa.gov/mediacenter/WCR%202016%20Whale%20Entanglements_3-26-17_Final.pdf

NPS (National Park Service). 1992. Value Analysis, Glacier National Park, Divide Creek. West Glacier, Montana.

NWFSC. 2015. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. Northwest Fisheries Science Center. December 21, 2015.

ODEQ (Oregon Department of Environmental Quality). 1995. National pollution discharge elimination system permit evaluation report. Facility Bourne Mining Corporation. December 11, 2003. File number 11355. 8pp.

ODFW (Oregon Department of Fish and Wildlife). 2012. Klamath watershed fish district stock status report, September 2012. ODFW, Klamath Falls, Oregon.

Olesiuk, P.F., M.A. Bigg, and G.M. Ellis.1990. Life history and population dynamics of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Report of the International Whaling Community (special issue).

Orr J. W., M. A. Brown, and D. C. Baker. 2000. Guide to Rockfishes (Scorpaenidae) of the Genera *Sebastes*, *Sebastolobus*, and *Abelosebastes* of the Northeast Pacific Ocean, Second Edition. NOAA Technical Memorandum NMFS-AFSC-117, 56 pages.

Palsson, W. A., T. Tsou, G. G. Bargmann, R. M. Buckley, J. E. West, M. L. Mills, Y. W. Cheng, and R. E. Pacunski. 2009. The Biology and Assessment of Rockfishes in Puget Sound. Fish Management Division, Fish Program, Washington Department of Fish and Wildlife. 208 pages.

Parametrix. 2011. Creosote Release from Cut/Broken Piles. Washington Department of Natural Resources. Olympia, Washington.

Parker, S. J., H. I. McElderry, P. S. Rankin, and R. W. Hannah. 2006. Buoyancy Regulation and Barotrauma in Two Species of Nearshore Rockfish. Transactions of the American Fisheries Society. Volume 135, pages 1213 to 1223.

PFMC (Pacific Fishery Management Council). 1998. Description and identification of essential fish habitat for the Coastal Pelagic Species Fishery Management Plan. Appendix D to Amendment 8 to the Coastal Pelagic Species Fishery Management Plan. Pacific Fishery Management Council, Portland, Oregon. December.

PFMC (Pacific Fishery Management Council). 2005. Amendment 18 (bycatch mitigation program), Amendment 19 (essential fish habitat) to the Pacific Coast Groundfish Fishery Management Plan for the California, Oregon, and Washington groundfish fishery. Pacific Fishery Management Council, Portland, Oregon. November.

PFMC. 2007. U.S. West Coast highly migratory species: Life history accounts and essential fish habitat descriptions. Appendix F to the Fishery Management Plan for the U.S. West Coast Fisheries for Highly Migratory Species. Pacific Fishery Management Council, Portland, Oregon. January.

PFMC. 2014. Appendix A to the Pacific Coast Salmon Fishery Management Plan, as modified by Amendment 18. Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon.

PFMC and MEW (Model Evaluation Workgroup). 2008. Chinook Fishery Regulation Assessment Model (FRAM) Base Data Development v. 3.0 (Auxiliary Report to FRAM Technical Documentation). October.

Popov, V.V., A.Y. Supin, D. Wang, K. Wang, L. Dong, and S. Wang. 2011a. Noise-induced temporary threshold shift and recovery in Yangtze finless porpoises Neophocaena phocaenoides asiaeorientalis. Journal of the Acoustical Society of America 130:574-584.

Popov, V.V., V.O. Klishin, D.I.. Nechaev, M.G. Pletenko, V.V. Rozhnov, A.Y. Supin, E.V. Sysueva, and M.B. Tarakanov. 2011b. Influence of acoustic noises on the white whale hearing thresholds. Doklady Biological Sciences 440:332-334.

Popper, A.N. 2003. Effects of anthropogenic sounds of fishes. Fisheries 28(10):24-31.

Popper, A.N., M.E. Smith, P.A. Cott, B.W. Hanna, A,O. MacGillivray, M.E. Austin, D.A. Mann. 2005. Effects of exposure to seismic airgun use on hearing of three fish species. J. Acoust. Soc. Am., 117:3958-3971.

Port of Seattle. 2013. About the Port. Available at: http://www.portseattle.org/About/Publications/Statistics/Seaport/Pages/Vessel-Calls.aspx

Port of Seattle. 2016. Cruise Seattle 2017 fact sheet. Received via email from Jon Sloan, Port of Seattle, to Jim Muck (USFWS/NMFS) on November 23, 2016.

Porter, M. and M. Nelitz. 2009. A future outlook on the effects of climate change on bull trout (*Salvelinus confluentus*) habitats in the Cariboo-Chilcotin. Prepared by ESSA Technologies Ltd.for Fraser Salmon and Watersheds Program, B.C. Ministry of Environment, and Pacific Fisheries Resource Conservation Council. 10 pp.

Pratt, K.L. 1985. Pend Oreille trout and char life history study. Idaho Department of Fish and Game, Boise, Idaho. 74 pp.

Pratt, K.L. 1992. A review of bull trout life history. Pages 5-9 *In* P.J. Howell, and D.V. Buchanan, eds. Proceedings of the Gearhart Mountain bull trout workshop, Oregon Chapter of the American Fisheries Society, Corvallis, OR.

Pratt, K.L., and J.E. Huston. 1993. Status of bull trout (*Salvelinus confluentus*) in Lake Pend Oreille and the lower Clark Fork River. Washington Water Power Company, Spokane, WA, December 1993. 200 pp.

Prinn, R., S. Paltsev, A. Sokolov, M. Sarofim, J. Reilly, and H. Jacoby. 2011. Scenarios with MIT integrated global systems model: significant global warming regardless of different approaches. Climatic Change 104:515-537.

PSP (Puget Sound Partnership). 2007. State of the Sound. Available at: http://www.psat.wa.gov/Publications/state_sound07/2007_stateofthesound.pdf.

Puget Sound Partnership. 2014. The 2014/2015 Action Agenda for Puget Sound.

Queen, S. 2013. Email to Jim Muck regarding the number of ships calls to Port of Seattle facilities. 6/28/2013.

Quigley, T.M., and S.J. Arbelbide. 1997. An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great Basins: Volume 3. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station 3:1174-1185.

Quinn, T. P. 2005. The behavior and ecology of pacific salmon and trout. 2005. University of Washington Press. 1st edition. 9 pp.

Ratliff, D.E., and P.J. Howell. 1992. The status of bull trout populations in Oregon. Pages 10-17 in: P.J. Howell and D.V. Buchanan (eds). Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis. 8 pp.

Redenbach, Z., and E. B. Taylor. 2002. Evidence for historical introgression along a contact zone between two species of char (Pisces: Salmonidae) in northwestern North America. Evolution 56:1021-1035.

Rensel Associates and PTI Environmental Services. 1991. Nutrients and phytoplankton in Puget Sound. Report for EPA Region 10, EPA 910/9-91-002. Office of Coastal Waters, U.S. Environmental Protection Agency, Seattle, Washington. 130 pp. plus appendices.

Reyff, J.A. 2006. Russian River Replacement Bridge at Geyserville: Underwater sound measurement data for driving permanent 48-inch CISS piles. Illingsworth and Rodkin, Inc., Petaluma, CA.

Rice, C.A., C.M. Greene, P. Moran, D.J. Teel, D.R. Kuligowski, R.R. Reisenbichler, E.M. Beamer, J.R. Karr, and K.L. Fresh. 2011. Abundance, Stock Origin, and Length of Marked and Unmarked Juvenile Chinook Salmon in the Surface Waters of Greater Puget Sound. Transactions of the American Fisheries Society, 140(1):170-189.

Rich, C.F. 1996. Influence of abiotic and biotic factors on occurrence of resident bull trout in fragmented habitats, Western Montana. Master's Thesis. Montana State University, Bozeman, MT. May 1996 pp.

Richardson, W.J., C.R. Greene, C.I. Malme, and D.H. Thomson. 1995. Marine Animals and Noise. Academic Press, San Diego, CA. 576 pp.

Rieman, B., and J. Clayton. 1997. Wildfire and native fish: Issues of forest health and conservation of sensitive species. Fisheries 22:6-14. 10 pp.

Rieman, B.E., D. Isaak, S. Adams, D. Horan, D. Nagel, C.H. Luce, and D. Myers. 2007. Anticipated climate warming effects on bull trout habitats and populations across the interior Columbia River Basin. Transactions of the American Fisheries Society 136(6):1552-1565.

Rieman, B.E., D.C. Lee, and R.F. Thurow. 1997. Distribution, status, and likely future trends of bull trout within the Columbia River and Klamath River basins. North American Journal of Fisheries Management 7:1111-1125.

Rieman, B.E., and F.W. Allendorf. 2001. Effective population size and genetic conservation criteria for bull trout. North American Journal of Fisheries Management 21:756-764.

Rieman, B.E., and J.B. Dunham. 2000. Metapopulations and salmonids: a synthesis of life history patterns and empirical observations. Ecology of Freshwater Fish 9:51-64. 14 pp.

Rieman, B.E., and J.D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, General Technical Report INT-302, Ogden, Utah, September 1993. 38 pp.

Rieman, B.E., and J.D. McIntyre. 1995. Occurrence of bull trout in naturally fragmented habitat patches of varied size. Transactions of the American Fisheries Society 124(3):285-296.

Rieman, B.E., and J.D. McIntyre. 1996. Spatial and temporal variability in bull trout redd counts. North American Journal of Fisheries Management 16:132-141.

Rieman, B.E., J.T. Peterson, and D.E. Myers. 2006. Have brook trout (*Salvelinus fontinalis*) displaced bull trout (*Salvelinus confluentus*) along longitudinal gradients in central Idaho streams? Canadian Journal of Fish and Aquatic Sciences 63:63-78.

Rode, M. 1990. Bull trout, *Salvelinus confluentus suckley*, in the McCloud River: status and recovery recommendations. Administrative Report Number 90-15. California Department of Fish and Game, Sacramento, California. 44 pp.

Romberg, G. P. 2005. Recontamination Sources at Three Sediment Caps in Seattle. Proceedings of the 2005 Puget Sound Georgia Basin Research Conference. Available at: http://your.kingcounty.gov/dnrp/library/wastewater/sedman/Denny/Denny_200506.pdf.

Ross, P. S., S.J. Jeffries, M.G. Ikonomou, and R.F. Addison. 1998. Elevated PCB levels in Puget Sound harbor seals (*Phoca vitulina*). Proceedings of Puget Sound Research '98. Puget Sound Water Quality Action Team, Olympia, Washington.

Roubal, W., T. Collier, and D. Malins. 1977. Accumulation and Metabolism of Carbon-14 Labeled Benzene, Naphthalene, and Anthracene by Young Coho Salmon. Archives of Environmental Contamination and Toxicology, 5:513-529.

Ruckelshaus, M.H., K. Currens, R. Fuerstenberg, W. Graeber, K. Rawson, N. Sands, and J. Scott. 2002. Planning ranges and preliminary guidelines for the delisting and recovery of the Puget Sound Chinook salmon Evolutionarily Significant Unit. Puget Sound Technical Recovery Team. April 30, 2002. 19 p.

Ruckelshaus, M.H., K.P. Currens, W.H. Graeber, R.R. Fuerstenberg, K. Rawson, N.J. Sands, and J.B. Scott. 2006. Independent populations of Chinook salmon in Puget Sound. National Marine Fisheries Service, Northwest Fisheries Science Center, NOAA Technical Memo. NMFSNWFSC-78. 125 p.

Ruggerone, G.T. and E.C. Volk. 2004. Residence time and growth of natural and hatchery Chinook salmon in the Duwamish Estuary and Elliott Bay, Washington: an application of otolith chemical and structural attributes. Prepared for U.S. Army Corps of Engineers, Seattle District, and Port of Seattle. Prepared by Natural Resources Consultants, Inc. and Washington Dept. Fish and Wildlife. Seattle, WA.

Ruggerone, G.T., T.S. Nelson, J. Hall, E. Jeanes. 2006. 2005 Juvenile Chinook Duwamish River Studies, Study 1: Habitat utilization, migration ntiming, growth, and diet of juvenile Chinook salmon in the Duwamish Rver and estuary. Technical report prepared for WRIA9. 91 pp.

Santulli, A., A. Modica, C. Messina, L. Ceffa, A. Curatolo, G. Rivas, G. Fabi, and V. D'Amelio. 1999. Biochemical responses of European sea bass (*Dicentrarchus labrax* L.) to the stress induced by off shore experimental seismic prospecting. Marine Pollution Bulletin 38(12):1105-1114.

Saunders, D.A., R.J. Hobbs, and C.R. Margules. 1991. Biological consequences of ecosystem fragmentation: A review. Conservation Biology 5:18-32. 15 pp.

Schill, D.J. 1992. River and stream investigations. Job Performance Report, Project F-73-R-13. Idaho Department of Fish and Game, Boise, Idaho. 66 pp.

Schlundt, C.E., J.J. Finneran, D.A. Carder, and S.H. Ridgway. 2000. Temporary shift in masked hearing thresholds of bottlenose dolphins, Tursiops truncatus, and white whales, Delphinapterus leucas, after exposure to intense tones. Journal of the Acoustical Society of America 107:3496-350.

Science Applications International Corporation (SAIC). 2011. Environmental sound panel for marbled murrelet underwater noise injury threshold. Science Applications International Corporation, Bothwell, Washington, August 31, 2011. 8 pp.

SAIC. 2012. Marbled Murrelet Hydroacoustic Science Panel II – Final Summary Report. Prepared for U.S. Navy, NAVFAC Northwest. September 4, 2012.

SDOT (Seattle Department of Transportation). 2012a. Elliott Bay Seawall Project. Noise and Vibration Discipline Report. Agreement No. T09-24. Prepared by Tetra Tech, Inc. Seattle WA. Available at: http://www.seattle.gov/transportation/docs/seawall/eis/14_AppendixE_NoiseVibration_FINAL.pdf.

SDOT. 2012b. Elliott Bay Seawall Project Water Resources Discipline Report. Prepared by Herrera Environmental Consultants, Inc. Seattle, Washington.

SDOT. 2012c. Elliott Bay Seawall Project Contaminated Materials Discipline Report. Submitted by Tetra Tech, Inc. Prepared by Floyd|Snider, Inc. Seattle, Washington.

SDOT. 2012d. Elliott Bay Seawall Project, Biological Assessment, Revised Final. Prepared by Tetra Tech, Inc., Seattle Washington. November 2012. 278 pp.

SDOT. 2012e. Elliott Bay Seawall Project Fish, Wildlife, and Vegetation Discipline Report. Prepared by Tetra Tech, Inc., Seattle, Washington.

Sedell, J.R., and F.H. Everest. 1991. Historic changes in pool habitat for Columbia River Basin salmon under study for TES listing. Pacific Northwest Research Station, Draft U.S. Department of Agriculture Report, Corvallis, Oregon. 6 pp.

Servizi, J.A., and D.W. Martens. 1991. Effect of temperature, season, and fish size on acute lethality of suspended sediments to coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 48(3):493-497.

Sexauer, H.M., and P.W. James. 1997. Microhabitat use by juvenile trout in four streams located in the eastern Cascades, Washington. Pages 361-370 *In* W.C. McKay, M.K. Brewin, and M. Monita, eds. Friends of the Bull Trout Conference Proceedings, Bull Trout Task Force (Alberta), c/o Trout Unlimited, Calgary, Alberta, Canada.

Shannon, J., Taylor Associates, Inc. 2001. Take permit annual report, memorandum to Western Washington Fish and Wildlife Office, U.S. Fish and Wildlife Service, January 18, 2001.

Shaffer, J. A., D. C. Doty, R. M. Buckley, and J. E. West. 1995. Crustacean community composition and trophic use of the drift vegetation habitat by juvenile split-nose rockfish, Sebastes diploproa. Marine Ecology Progress Series. 123:13-21

Shepsis, V. 2012. Email to George Ritchotte (WSDOT) discussing sediment analysis and numerical modeling of current velocities in Elliott Bay for the Colman Dock Project. Coast and Harbor Engineering, Edmonds, WA. 10/30/12.

Shively, D., C. Allen, T. Alsbury, B. Bergamini, B. Goehring, T. Horning and B. Strobel. 2007.

Shuter, B.J., and Meisner, J.D. 1992. Tools for assessing the impact of climate change on freshwater fish populations. GeoJournal 28(1):7-20. 22 pp.

Silcox, R.L., W.R. Geyer, and G.A. Cannon. 1981. Physical transport processes and circulation in Elliott Bay. NOAA Technical Memorandum: OMPA-8, 45 pp.

Simenstad, C.A., K.L. Fresh and E.O. Salo. 1982. The role of Puget Sound and Washington coastal estuaries in the life history of Pacific salmon: an unappreciated function. pp 343–364 in V.S. Kennedy (ed.). Estuarine Comparisons. Academic Press, New York.

Simenstad, C.A., R.M. Thom and D.K. Shreffer. 1999. Impacts of ferry terminals on juvenile salmon migrating along Puget Sound shorelines, phase I: Synthesis of state of knowledge. Report prepared for Washington State Transportation Commission.

Simpson, J.C., and R.L. Wallace. 1982. Fishes of Idaho. University of Idaho Press, Moscow, ID. 93 pp.

Smillie, G. M., and D. Ellerbroek. 1991. Flood hazard evaluation for Divide and Wild creeks, Glacier National Park. Technical Report NPS/NRWRD/NRTR-91/02. Water Resources Division, National Park Service, Fort Collins, Colorado.

Smith, P. 2008. Risks to human health and estuarine ecology posed by pulling out creosote treated timber on oyster farms. Aquatic Toxicology, 86:287–298.

Sobocinski, K., J. Cordell, and C. Simenstad. 2010. Effects of shoreline modifications on supratidal macroinvertebrate fauna on Puget Sound, Washington beaches. Estuaries and Coasts 33(3):699–711. Available at: http://www.springerlink.com/content/j0uqk7m42224q308/fulltext.pdf

Sogard, S. M., S. A. Berkeley, and R. Fisher. 2008. Maternal effects in rockfishes *Sebastes* spp.: a comparison among species. Marine Ecology Progress Series. Volume 360, pages 227 to 236.

Solomon, S., D. Qin, M. Manning, R.B. Alley, T. Berntsen, N.L. Bindoff, Z. Chen, A. Chidthaisong, J.M. Gregory, G.C. Hegerl, M. Heimann, B. Hewitson, B.J. Hoskins, F. Joos, J. Jouzel, V. Kattsov, U. Lohmann, T. Matsuno, M. Molina, N. Nicholls, J. Overpeck, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, R. Somerville, T.F. Stocker, P. Whetton, R.A. Wood and D. Wratt, 2007: Technical Summary. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene, et al. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals 33(4):411-521.

Song, J.K., D.A. Mann, P.A. Cott, B.W. Hanna, and A.N. Popper. 2008. The inner ears of northern Canadian freshwater fishes following exposure to seismic air gun sounds. Journal of the Acoustical Society of America 124(2): 1360-66.

Spruell, P., B.E. Rieman, K.L. Knudsen, F.M. Utter, and F.W. Allendorf. 1999. Genetic population structure within streams: microsatellite analysis of bull trout populations. Ecology of Freshwater Fish 8:114-121.

Spruell P., A.R. Hemmingsen, P.J. Howell, N. Kanda1 and F.W. Allendorf. 2003. Conservation genetics of bull trout: Geographic distribution of variation at microsatellite loci. Conservation Genetics 4: 17–29. 14 pp.

SSPS (Shared Strategy for Puget Sound). 2007. Puget Sound salmon recovery plan. Volume 1, recovery plan. Shared Strategy for Puget Sound, editor, Seattle, Washington.

Stadler, J.H. 2002. Pers. Comm. Notes from site visit, Winslow Ferry Terminal, to observe pile driving and monitoring of noise levels and effects to fishes.

Stevick, P.T. 1999. Age-length relationships in humpback whales: A comparison of strandings in the western north Atlantic with commercial catches. Marine Mammal Science, 15(3):725-737 (July 1999).

Stewart, D.B., N.J. Mochnacz, C.D. Sawatzky, T.J. Carmichael, and J.D. Reist. 2007. Fish life history and habitat use in the Northwest territories: Bull trout (*Salvelinus confluentus*). Department of Fisheries and Oceans, Canadian Manuscript Report of Fisheries and Aquatic Sciences 2801, Winnipeg, MB, Canada, 2007. 54 pp

Stewart, I.J. 2007. Status of the U.S. canary rockfish resource in 2007. Stock Assessment and Fishery Evaluation. Pacific Fishery Management Council, 2130 SW Fifth Ave., Suite 224, Portland OR. 362 pages.

Strickland, R. M. 1983. The fertile fjord: Plankton in Puget Sound. University of Washington, Washington Sea Grant Program, Seattle, Washinton.

Studebaker, R. S., K. N. Cox, and T. J. Mulligan. 2009. Recent and historical spatial distributions of juvenile rockfish species in rocky intertidal tide pools, with emphasis on black rockfish. Transactions of the American Fisheries Society. Volume 138, pages 645 to 651.

Stuhmiller, J.H., K.H.H. Ho, M.J. Vander Vost, and K.T. Dodd. 1996. A model of blast overpressure injury to the lung. Journal of Biomechanics 29(2):227-34.

Tagal, M ., K. C. Massee, N. Ashton, R. Campbel l. P. Plesha, and M. B. Rust. 2002. Larval development of yelloweye rockfish, *Sebastes ruberrimus.* National Oceanic and Atmospheric Administration, Northwest Fisheries Science Center.

Taylor, B.E., S. Pollard, and D. Louie. 1999. Mitochondrial DNA variation in bull trout (*Salvelinus confluentus*) from northwestern North America: implications for zoogeography and conservation. Molecular Ecology 8:1155-1170. 16 pp.

Teachout, E. 2010. Evaluating the effects of elevated underwater sound pressure levels from pile driving on the marbled murrelet and the bull trout. Washington Fish and Wildlife Office, U.S. Fish and Wildlife Service, Lacey, Washington, 26 pp.

Teachout, E. 2012. Email, dated 8-31-12, from Burt miller, WSDOT, stating observations of two marbled murrelet near the grain elevator in Myrtle Edwards Park north of downtown Seattle.

Thomas, G. 1992. Status of bull trout in Montana. Montana Department of Fish, Wildlife and Parks, Helena, MT, August 1992. 83 pp.

Thomsen, F., K. Ludemann, R. Kafemann, and W. Piper. 2006. Effects of offshore wind farm noise on marine mammals and fish. Biola. Hamburg, Germany on behalf of COWRIE Ltd.

Toft, J. 2013a. Email to Jim Muck (NMFS/USFWS) forwarding Chinook salmon number caught in Elliott Bay, both along seawall and reference sites. University of Washington. 2/8/13.

Toft, J. 2013b. Email to Jim Muck (NMFS/USFWS) regarding Chinook juvenile size of fish caught along the seawall. University of Washington. 5/29/13.

Toft, J. and J. Cordell. 2006. Olympic Sculpture Park: results from pre-construction biological monitoring of shoreline habitats. Technical Report SAFS-UW-0601, School of Aquatic and Fishery Sciences, University of Washington. Prepared for Seattle Public Utilities, City of Seattle.

Toft, J., A. Ogston, S. Heerhartz, J. Cordell, E. Armbrust, and C. Levy. 2010. Olympic Sculpture Park: Year 3 Monitoring and Shoreline Enhancements. SAFS-UW-1002. Prepared for Seattle Public Utilities, City of Seattle. University of Washington, Seattle, WA.

Toft, J., J. Cordell, C. Simenstad, and L. Stamatiou. 2004. Fish distribution, abundance, and behavior at nearshore habitats along City of Seattle marine shorelines, with an emphasis on juvenile salmonids. Technical Report SAFS-UW-0401, School of Aquatic and Fishery Sciences, University of Washington. Prepared for Seattle Public Utilities, City of Seattle.

Toft, J.D., J.R. Cordell, C.A. Simenstad, and L.A. Stamatiou. 2007. Fish distribution, abundance, and behavior along city shoreline types in Puget Sound. North American Journal of Fisheries Management 27: 465-480.

Toft, J., A. Ogston, S. Heerhartz, J. Cordell, E. Armbrust, and C. Levy. 2010. Olympic Sculpture Park: Year 3 Monitoring of Shoreline Enhancements. School of Aquatic and Fisheries Sciences, and School of Oceanography, University of Washington. SAFS-UW-1002.

Toft, J. J. Cordell, F. Stevick, and S. Munsch. 2012a. Status Report #1: Ellioott Bay Seawall Fish Survey. University of Washington School of Aquatic and Fishery Sciences. Prepared for the Seattle Department of Transportation. March 30, 2012.

Toft, J., J. Cordell, F. Stevick, S. Munsch, C. Levy, E. Morgan, and M. Caputo. 2012b. Status Report #2: Elliott Bay Seawall Fish Survey. University of Washington School of Aquatic and Fishery Sciences. Prepared for the Seattle Department of Transportation. June 29, 2012.

Toft, J., J. Cordell, F. Stevick, S. Munsch, C. Levy, E. Morgan, and M. Caputo. 2012c. Status Report #3: Elliott Bay Seawall Fish Survey. University of Washington School of Aquatic and Fishery Sciences. Prepared for the Seattle Department of Transportation. September 29, 2012.

Toft, J., J. Cordell, S. Munsch, C. Levy, E. Morgan, and M. Caputo. 2012d. Status Report #4: Elliott Bay Seawall Fish Survey. University of Washington School of Aquatic and Fishery Sciences. Prepared for the Department of Transportation. December 28, 2012.

Toft, J., J. Cordell, S. Munsch, C. Levy, E. Morgan, and M. Caputo. 2013a. Status Report #5: Elliott Bay Seawall Fish Survey. University of Washington School of Aquatic and Fishery Sciences. Prepared for the Seattle Department of Transportation. March 29, 2013.

Toft, J., J. Cordell, S. Munsch, C. Levy, E. Morgan, and M. Caputo. 2013b. Status Report #6: Elliott Bay Seawall Fish Survey. University of Washington School of Aquatic and Fishery Sciences. Prepared for the Seattle Department of Transportation. May 30, 2013.

Tolimieri, N., and P. S. Levin. 2005. The roles of fishing and climate in the population dynamics of bocaccio rockfish. Ecological Applications. Volume 15, pages 458 to 468.

Turnpenny, A.W.H., and J. Nedwell. 1994. The effects on marine fish, diving mammals and birds of underwater sound generated by seismic surveys. Fawley Aquatic Research Laboratories Limited, Marine and Freshwater Biology Unit. Report FCR 089/94, Southampton, Hampshire, UK. October 1994. 40 pp.

Turnpenny, A.W.H., K.P. Thatcher, R. Wood, and J. Nedwell. 1994. The effects on fish and other marine animals of high-level underwater sound. Fawley Aquatic Research Laboratory, Ltd., Marine and Freshwater Biology Unit. Report FRR 127/94, Southampton, United Kingdom. SOSMM0906; Vashon Island BO; Navy EOD pp.

USACE (United States Army Corps of Engineers). 2008. Revised preliminary existing conditions report. Alaskan Way Seawall Replacement Project feasibility study. Environmental impact statement – existing conditions. U.S. Army Corps of Engineers, Seattle District. March.

URS Engineers and Evans-Hamilton. 1986. Elliott Bay oceanographic studies, Final report. Prepared for the Municipality of Metropolitan Seattle.

USDA (U.S. Department of Agriculture), and USDI (U.S. Department of the Interior). 1995. Decision Notice/Decision Record Finding of No Significant Impact, Environmental Assessment for the Interim Strategies for Managing Anadromous Fish-producing Watersheds in Eastern Oregon, and Washington, Idaho, and portions of California (PACFISH). 211 pp.

USDC (U.S. Department of Commerce). 2003. Regulations governing the taking and importing of marine mammals; eastern north Pacific Southern Resident killer whales. Department of Commerce, National Oceanic and Atmospheric Administration. Federal Register 68(103):31980-31983.

USDC (U.S. Department of Commerce). 2005. Endangered and threatened wildlife and plants: Endangered status for Southern Resident killer whales. Department of Commerce, National Oceanic and Atmospheric Administration. Federal Register 70(222):69903-69912.

USEPA and PSWQAT (Puget Sound Water Quality Action Team). 1999. Temporal trends in contaminants in Puget Sound harbor seals. Available at: http://www.cascadiaresearch.org/reports/rep-99contam.pdf.

USFWS (U.S. Fish and Wildlife Service). 1996. Policy Regarding the Recognition of Distinct Vertebrate Population Segments under the Endangered Species Act. Federal Register Vol. 61 4722-4725.

USFWS. 1997. Recovery Plan for the Threatened Marbled Murrelet (*Brachyramphus Marmoratus*) in Washington, Oregon, and California. Portland, Oregon. 203 pp.

USFWS (U.S. Fish and Wildlife Service). 1998. Determination of threatened status for the Klamath River and Columbia River distinct population segments of bull trout. Federal Register Vol. 63 31647-31674. 28 pp.

USFWS (U.S. Fish and Wildlife Service). 1999. Determination of threatened status for bull trout in the coterminous United States; Final Rule. Federal Register Vol. 64 58190-58933. 25 pp.

USFWS (U.S. Fish and Wildlife Service). 2002a. Bull trout (*Salvelinus confluentus*) draft recovery plan - Chapter 1: Introduction. U.S. Fish and Wildlife Service, Portland, Oregon, October, 2002, 137 pp.

USFWS (U.S. Fish and Wildlife Service). 2002b. Bull trout (*Salvelinus confluentus*) draft recovery plan - Chapter 2: Klamath River. U.S. Fish and Wildlife Service, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 2004a. Draft Recovery Plan for the Coastal-Puget Sound distinct population segment of bull trout (*Salvelinus confluentus*). Volume I: Puget Sound Management Unit, 389+xvii pp and Volume II: Olympic Peninsula Management Unit, 277+xvi pp, Portland, Oregon

USFWS (U.S. Fish and Wildlife Service). 2008a. Bull trout (*Salvelinus confluentus*) 5 year review: summary and evaluation. U.S. Fish and Wildlife Service, Portland, Oregon, April 25, 2008. 55 pp.

USFWS (U.S. Fish and Wildlife Service). 2008b. Bull trout draft core area templates - complete core area by core area analysis. W. Fredenberg and J. Chan, editors. U. S. Fish and Wildlife Service. Portland, Oregon. 1,895 pages.

USFWS (U.S. Fish and Wildlife Service). 2010. Revised designation of critical habitat for bull trout in the coterminous United States. Federal Register Vol 75, No. 200. 63898-64070.

USFWS. 2012. Evaluating the effects of underwater sound form pile driving on the marbled murrelet and the bull trout. 1/4/12. By Emily Teachout. U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, Lacey, WA. 35 pp.

USFWS. 2015. Recovery Plan for the Coterminous United States Population of Bull Trout (*Salvelinus confluentus*). Portland, OR. xii + 179 pp.

USFWS (U.S. Fish and Wildlife Service). 2015a. Coastal recovery unit implementation plan for bull trout (*Salvelinus confluentus*). U.S. Fish and Wildlife Service, Lacey, Washington, and Portland, Oregon. 155 pp.

USFWS (U.S. Fish and Wildlife Service). 2015b. Klamath recovery unit implementation plan for bull trout (*Salvelinus confluentus*). U.S. Fish and Wildlife Service, Klamath Falls, Oregon. 35 pp.

USFWS (U.S. Fish and Wildlife Service). 2015c.Mid-Columbia recovery unit implementation plan for bull trout (*Salvelinus confluentus*). U.S. Fish and Wildlife Service, Portland, Oregon. 345 pp.

USFWS (U.S. Fish and Wildlife Service). 2015d. Columbia headwaters recovery unit implementation plan for bull trout (*Salvelinus confluentus*). U.S. Fish and Wildlife Service, Kalispell, Montana, and Spokane, Washington. 179 pp.

USFWS (U.S. Fish and Wildlife Service). 2015e. Upper Snake recovery unit implementation plan for bull trout (*Salvelinus confluentus*). U.S. Fish and Wildlife Service, Boise, Idaho. 113 pp.

USFWS (U.S. Fish and Wildlife Service). 2015f. St. Mary recovery unit implementation plan for bull trout (*Salvelinus confluentus*). U.S. Fish and Wildlife Service, Kalispell, Montana. 30 pp.

USFWS (U.S. Fish and Wildlife Service) and NMFS (National Marine Fisheries Service). 1998. Consultation handbook: procedures for conducting consultation and conference activities under Section 7 of the Endangered Species Act. 315pp.

USGS (United States Geological Survey). 2011. NAS - Nonindigenous Aquatic Species. Specimen Information. Accessed May 15, 2011 at: http://nas.er.usgs.gov/queries/SpecimenViewer.aspx?SpecimenID=252793.

USGS (United States Geological Survey). 2016. Bathymetry Data – Elliott Bay. From http://walrus.wr.usgs.gov/pacmaps/ps-duw.html. Accessed 11/16/16.

Varanasi, U., E. Casillas, M. Arkoosh, T. Hom, D. Misitano, D. Brown, S. Chan, T. Collier, B. McCain, and J. Stein. 1993. Contaminant Exposure and Associated Biological Effects in Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) from Urban and Nonurban Estuaries of Puget Sound. National Marine Fisheries Service Northwest Fisheries Science Center. Seattle, Washington.

Wade, P. R., T. J. Quinn II, J. Barlow, C. S. Baker, A. M. Burdin, J. Calambokidis, P. J. Clapham, E. Falcone, J. K. B. Ford, C. M. Gabriele, R. Leduc, D. K. Mattila, L. RojasBracho, J. Straley, B. L. Taylor, J. Urbán R., D. Weller, B. H. Witteveen, and M. Yamaguchi. 2016. Estimates of abundance and migratory destination for North Pacific humpback whales in both summer feeding areas and winter mating and calving areas. Paper SC/66b/IA21 submitted to the Scientific Committee of the International Whaling Commission, June 2016, Bled, Slovenia.

Ward, E.J., E.E. Holmes, and K.C. Balcomb. 2009. Quantifying the effects of prey abundance on killer whale reproduction. Journal of Applied Ecology 46: 632-640.

Wartzok, D., and D.R. Ketten. 1999. Marine mammal sensory systems. Pages 117-175 in J.E. Reynolds III and S.A. Rommel, eds. Biology of Marine Mammals. Washington, D.C. Smithsonian Institution Press.

Washington, P. 1977. Recreationally important marine fishes of Puget Sound, Washington. National Oceanic and Atmospheric Administration, Northwest and Alaska Fisheries Center. 122 pages.

Washington, P. M., R. Gowan, and D. H. Ito. 1978. A biological report on eight species of rockfish (*Sebastes* spp.) from Puget Sound, Washington. Northwest and Alaska Fisheries Center Processed Report, National Marine Fisheries Service, Seattle. 50 pages.

Waters, T.F. 1995. Sediment in streams: Sources, biological effects, and control. American Fisheries Society, Monograph 7, Bethesda, Maryland.

Watson, G., and T.W. Hillman. 1997. Factors affecting the distribution and abundance of bull trout: an investigation at hierarchical scales. North American Journal of Fisheries Management 17(2):237-252.

WDFW (Washington Department of Fish and Wildlife). 1997. Washington Department of Fish and Wildlife hatcheries program. Operations program - Lewis river complex for January 1, 1997 to December 31,1997. Washington Department of Fish and Wildlife, Olympia, WA.

WDFW (Washington Department of Fish and Wildlife). 1998. Washington State Salmonid Stock Inventory - Bull Trout/Dolly Vardin. 444 pp.

WDFW (Washington State Department of Fish and Wildlife). 2002a. Salmonid Stock Inventory (SaSI). WDFW, Wildlife Program. Olympia, WA. Duwamish/Green – Green River (Duwamish) summer steelhead. Stock Report. Available at: http://wdfw.wa.gov/webmaps/salmonscape/sasi/full_stock_rpts/6168.pdf.

WDFW (Washington State Department of Fish and Wildlife). 2002b. Salmonid Stock Inventory (SaSI). WDFW, Wildlife Program. Olympia, WA. Duwamish/Green – Green River (Duwamish) winter steelhead. Stock Report. Available at: http://wdfw.wa.gov/webmaps/salmonscape/sasi/full_stock_rpts/6175.pdf.

WDFW (Washington State Department of Fish and Wildlife). 2002c. Salmonid Stock Inventory (SaSI). WDFW, Wildlife Program. Olympia, WA. Green River (Duwamish) Chinook Salmon Stock Report. Available at: http://wdfw.wa.gov/webmaps/salmonscape/sasi/full_stock_rpts/1160.pdf.

WDFW (Washington State Department of Fish and Wildlife). 2002d. Salmonid Stock Inventory (SaSI). WDFW, Wildlife Program. Olympia, WA. Snohomish-Skykomish Chinook Salmon Stock Report. Available at: http://wdfw.wa.gov/webmaps/salmonscape/sasi/full_stock_rpts/1106.pdf.

WDFW (Washington State Department of Fish and Wildlife). 2002e. Salmonid Stock Inventory (SaSI). WDFW, Wildlife Program. Olympia, WA. Snohomish-Snoqualmie Chinook Salmon Stock Report. Available at: http://wdfw.wa.gov/webmaps/salmonscape/sasi/full_stock_rpts/1108.pdf.

WDFW (Washington State Department of Fish and Wildlife). 2010. Unpublished locations of yelloweye rockfish, canary rockfish and bocaccio within the Puget Sound/Georgia Basin. On file with the National Marine Fisheries Service, 7600 Sandpoint Way NE, Seattle, WA 98115.

WDFW. 2011a. Unpublished catch data from 2003 – 2009. On file with the National Marine Fisheries Service, Sandpoint Way NE, Seattle, WA 98115.

WDFW. 2011b. Surf smelt fact sheet. Available at: http://wdfw.wa.gov/publications/pub.php?id=01219.

WDFW. 2011c. The Priority Habitats and Species (PHS) Program; requested PHS data for Elliott Bay Seawall Project study area. Received April 2011. Available at: http://wdfw.wa.gov/conservation/phs/.

WDFW. 2017. Salmon and Steelhead Species in Washington: Chinook population stock assessment. Available at https://test-fortress.wa.gov/dfw/score/score/species/chinook.jsp?species=Chinook

WDFW and NWIFC (Northwest Indian Fisheries Commission). 2010. 2010-11 Co-Managers' List of Agreed Fisheries. May1, 2010 – April 30, 2011. State of Washington WDFW, Olympia WA, NWIFC, Olympia, WA.

WDFW, FishPro Inc., and Beak Consultants. 1997. Grandy Creek trout hatchery biological assessment. Washington Department of Fish and Wildlife, Olympia, WA, March 1997. 47 pp.

WDNR (Washington Department of Natural Resources). 2001. Washington State Exotics Expedition 2000, A rapid survey of exotic 8 species in the shallow waters of Elliott Bay, Totten and Eld Inlets, and 9 Willapa Bay. Olympia, Washington.

WDOE (Washington State Department of Ecology). 2002. Evaluating criteria for the protection of freshwater aquatic life in Washington's surface water quality standards - dissolved oyxgen: Draft discussion paper and literature summary. Washington Department of Ecology, Publication Number 00-10-071, Olympia, WA, December 2002. 90 pp.

WDOE. 2009. Spill Prevention, Preparedness, and Response Program. 2007-2008 Report. Vol. 11. No. 1. 09-08-003.

Weis, L. J. 2004. The effects of San Juan County, Washington, marine protected areas on larval rockfish production. Master of Science thesis, University of Washington, Seattle, WA. 55 pages.

Weitkamp, D.E., G.T. Ruggerone, L. Sacha, J. Howell, and B. Bachen. 2000. Factors affecting Chinook populations, background report. Prepared by Parametrix, Inc, Natural Resources Consultants, and Cedar River Associates for City of Seattle, WA. 224 p.

West, J.E. and S.M. O'Neill. 1998. Persistent pollutants and factors affecting their accumulation in rockfishes (*Sebastes* spp.) from Puget Sound, Washington. Puget Sound Water Quality Action Team, Olympia, Washington.

West, J., O'Neil, S., Lomax, D., and L. Johnson. 2001. Implications for reproductive health in rockfish (Sebastes spp.) from Puget Sound exposed to polychlorinated biphenyls. Puget Sound Research 2001. Available at http://wdfw.wa.gov/publications/O1041/wdfwO1041.pdf

Weston Solutions and Pascoe Environmental Consulting. 2006. Jimmycomelately piling removal monitoring project. Final Report prepared for the Jamestown S'Klallam Tribe. Sequim, WA. 109 p.

Westrheim, S. J., and W. R. Harling. 1975. Age-length relationships for 26 scorpaenids in the northeast Pacific Ocean. Technical Report 565, Fisheries and Marine Service Research Division, Nanaimo, British Columbia. 12 p.

Whiteley, A.R., P. Spruell; F.W. Allendorf. 2003. Population Genetics of Boise Basin Bull Trout (*Salvelinus confluentus*). University of Montana, Division of Biological Sciences. Report to the U.S. Forest Service, Rocky Mountain Research Station, Boise, ID. 37 pp.

Whitesel, T. A., J. Brostrom, T. Cummings, J. Delavergne, W. Fredenberg, H. Schaller, P. Wilson, and G. Zydlewski. 2004. Bull trout recovery planning: a review of the science associated with population structure and size. Science team report #2004-01, U.S. Fish and Wildlife Service, Portland, Oregon. 68 pp.

Wiley, M.L., J.B. Gaspin, and J.F. Goertner. 1981. Effects of underwater explosions on fish with a dynamical model to predict fishkill. Ocean Science and Engineering 6(2):223-84.

Wiles, G. J. 2016. Periodic status review for the killer whale in Washington. Washington Department of Fish and Wildlife, Olympia, Washington. 26+iii pp.

Williams, G.D., R.M. Thom, J.E. Starkes, J.S. Brennan, J. P. Houghton, D. Woodruff, P.L. Striplin, M. Miller, M. Pedersen, A. Skillman, R. Kropp, A. Borde, C. Freeland, K. McArthur, V. Fagerness, S. Blanton, and L. Blackmore. 2001. Reconnaissance Assessment of the State of the Nearshore Ecosystem: Eastern Shore of Central Puget Sound, Including Vashon and Maury Islands (WRIAs 8 and 9). J.S. Brennan, Editor. Report prepared for King County Department of Natural Resources, Seattle, WA.

Windward Environmental. 2010. Lower Duwamish Waterway Remedial Investigation Report. Submitted to the U.S. Environmental Protection Agency and the Washington Department of Ecology. Available at: http://cleanupsites.org/t115/documents/Appendix%20C/Windward%20Environmental%20LLC%202010.pdf.

Winter, D.F. 1977. Studies of circulation and primary production in deep inlet environments. Environmental Protection Agency, Ecology Research Series, Report: EPA 600/3-77-049, EPA, Corvallis, Oregon.

Wipfli, M. 1997. Terrestrial invertebrates as salmonid prey and nitrogen sources in streams: contrasting old-growth and young-growth riparian forests in southeastern Alaska, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 54(6): 1259–1269.

WISC (Washington Invasive Species Council). 2008. Washington State Aquatic Nuisance Species (ANS) Watch List. April 14. Available at: http://www.invasivespecies.wa.gov/documents/ANSCwatchlist.pdf.

Wissmar, R., J. Smith, B. McIntosh, H. Li, G. Reeves, and J. Sedell. 1994. A history of resource use and disturbance in riverine basins of eastern Oregon and Washington (early 1800s-1990s). Northwest Science 68:1-35. 18 pp.

WSDOT (Washington State Department of Transportation). 2004. SR 99: Alaskan Way Viaduct and Seawall Replacement Project Draft Environmental Impact Statement. March.

WSDOT (Washington State Department of Transportation). 2006. Alaskan Way Viaduct & Seawall Replacement Project; Seattle Waterfront Seawall marine habitat survey. Prepared by Taylor Associates, Inc., Seattle, Washington. October.

WSDOT (Washington State Department of Transportation). 2016a. Washinton State Department of Transportation's Ferry Schedule website for Seattle to Bainbridge Island and Bremerton. Available at http://www.wsdot.com/Ferries/Schedule/. Accessed November 28, 2016.

WSDOT. 2016b. WSF Colman Dock Test Pile Project. Underwater Sound Level Report: Colman Dock Test Pile Project 2016. Washington State Department of Transportation. Seattle, WA. June 2016. 59 pp.

WSDOT, 2017. Biological Assessment Preparation for Transportation Projects - Advanced Training Manual. Chapter 7 Construction Noise Impact Assessment. Version 4-2017. Available at https://www.wsdot.wa.gov/NR/rdonlyres/448B609A-A84E-4670-811B-9BC68AAD3000/0/BA_ManualChapter7.pdf.

Yamanaka, K.L. and L.C. Lacko, 2001. Inshore Rockfish (*Sebastes ruberrimus, S. maliger, S. caurinus, S. melanops, S. nigrocinctus,* and *S. nebulosus*) Stock Assessment for the West Coast of Canada and Recommendations for Management. Can. Sci. Adv. Sec. Res. Doc. 2001/139 : 102 p.

Yelverton, J.T., and D.R. Richmond. 1981. Underwater explosion damage risk criteria for fish, birds, and mammals. In Anonymous 102nd Meeting of the Acoustical Society of America, November 30 - December 04, 1981, Department of Biodynamics, Lovelace Biomedical and Environmental Research Institute, Albuquerque, New Mexico. 36 pp.

Yelverton, J.T., D.R. Richmond, R.E. Fletcher, and R.K. Jones. 1973. Safe distances from underwater explosions for mammals and birds. Lovelace Foundation for Medical Education and Research, Albuquerque, NM. September 26, 1973. 64 pp

Yelverton, J.T., D.R. Richmond, W. Hicks, K. Saunders, and R.E. Fletcher. 1975. The relationship between fish size and their response to underwater blast. Report prepared for the Defense Nuclear Agency. Report AD-A015-970, Albuquerque, New Mexico. 39 pp.

Ziller, J.S. 1992. Distribution and relative abundance of bull trout in the Sprague River subbasin, Oregon. Pages 18-29 in Howell, P.J. and D.V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis, OR. 12 pp.

Zischke, J. 2013. Phone conversation between Jay Zischke (Suquamish Tribe) and Jim Muck (NMFM/USFWS) regarding Tribal fishing in Elliott Bay and the North of Cape Falcon agreements. January 23, 2013.

6. APPENDICES

APPENDIX A
BIOLOGICAL EFFECTS OF SEDIMENT ON SALMONIDS AND THEIR HABITAT

Introduction

As a stream or river flows downslope, it transports sediment and dissolved matter (Skinner and Porter 2000, p. 252). A stream has a natural amount of sediment that is transported through the system that varies throughout the year in response to natural hydrological changes (Galbraith et al. 2006, p. 2488). The amount of sediment that a stream can transport annually is based on numerous factors: precipitation, surface water transport, erosion, topography, geology, streamflow, riparian vegetation, stream geomorphologic characteristic, human disturbance, atmospheric deposition, etc. (Bash et al. 2001, p. 7; Berry et al. 2003, p. 7). Therefore, different watersheds will have different levels or concentrations of turbidity and suspended sediment. A glaciated stream will have higher sediment levels than a spring fed stream (Ahearn 2002, p .2; Uehlinger et al. 2002, p. 1).

Many watersheds are subject to anthropogenic disturbances that can produce substantial inputs of sediments into streams (Barrett et al. 1992, p. 437). Turbidity, suspended solids, sediment, and siltation have been consistently listed as impairments in the U.S. Environmental Protection Agency's (EPA) 305(b) water quality reports in rivers and streams, lakes, reservoirs, ponds, wetlands, and oceans shoreline waters (Berry et al. 2003, p. 4). The EPA's 305(b) list provides the U.S. Congress and the public a means of determining or assessing the current condition of water quality within each individual state. Excessive sedimentation, natural and anthropogenic, has been estimated to occur in 46 percent of all streams and rivers in the U.S. and is considered the most important factor limiting fish habitat and causing water quality impairment (Berry et al. 2003, pp. 4, 7; Judy et al. 1985 as cited in Henley et al. 2000, p. 126). One of the most pervasive influences of land-use activities on stream ecosystems is an increase in sediment yield resulting from point source discharges associated with in-stream activities (Suren and Jowett 2001, p. 725).

Aquatic organisms have adapted to the natural variation in sediment load that occurs seasonally within the stream (Birtwell 1999, p. 7; FAO 1976, pp. 13, 15). Field experiments have found a thirty-fold increase in salmonids' (coho salmon) tolerance to suspended solids between August and November when naturally occurring concentrations are expected to be high (Cederholm and Reid 1987, p. 388).

The introduction of sediment in excess of natural amounts can have multiple adverse effects on salmonids and their habitat (Berry et al. 2003, p. 7; Rhodes et al. 1994, pp. 16-21). The effect of sediment beyond natural background conditions can be fatal at high levels. Embryo survival and subsequent fry emergence success have been highly correlated to percentage of fine material within the streambed (Shepard et al. 1984, pp. 146, 152). Low levels of sediment may result in sublethal and behavioral effects such as increased activity, stress, and emigration rates; loss or reduction of foraging capability; reduced growth and resistance to disease; physical abrasion;

clogging of gills; and interference with orientation in homing and migration (Barrett et al. 1992, p. 437; Bash et al. 2001, p. 9; Berry et al. 2003, p. 33; Lake and Hinch 1999, p. 865; McLeay et al. 1987, p. 671; Newcombe and MacDonald 1991, pp. 72, 76, 77; Vondracek et al. 2003, p. 1005; Watts et al. 2003, p. 551). The effects of increased suspended sediments can cause changes in the abundance and/or type of food organisms, alterations in fish habitat, and long-term impacts to fish populations (Anderson et al. 1996, pp. 1, 9, 12, 14, 15; Reid and Anderson 1999, pp. 1, 7-15). No threshold has been determined in which fine-sediment addition to a stream is harmless (Suttle et al. 2004, p. 973). Even at low concentrations, fine-sediment deposition can decrease growth and survival of juvenile salmonids.

Aquatic systems are complex interactive systems, and isolating the effects of sediment to fish is difficult (Castro and Reckendorf 1995, pp. 2-3). The effects of sediment on receiving water ecosystems are complex and multi-dimensional, and further compounded by the fact that sediment flux is a natural and vital process for aquatic systems (Berry et al. 2003, p. 4). Environmental factors that affect the magnitude of sediment impacts on salmonids include duration of exposure, frequency of exposure, toxicity, temperature, life stage of fish, angularity and size of particle, severity/magnitude of pulse, time of occurrence, general condition of biota, and availability of and access to refugia (Bash et al. 2001, p. 11). Potential impacts caused by excessive suspended sediments are varied and complex and are often masked by other concurrent activities (Newcombe 2003, p. 530). The difficulty in determining which environmental variables act as limiting factors has made it difficult to establish the specific effects of sediment impacts on fish (Chapman 1988, p. 2). For example, excess fines in spawning gravels may not lead to smaller populations of adults if the amount of juvenile winter habitat limits the number of juveniles that reach adulthood. Often there are multiple independent variables with complex inter-relationships that can influence population size.

The ecological dominance of a given species is often determined by environmental variables. A chronic input of sediment could tip the ecological balance in favor of one species in mixed salmonid populations or in species communities composed of salmonids and nonsalmonids (Everest et al. 1987, p. 120). This document identifies the biological effects of sediment on fish and their habitat including the different life stage(s) affected by sediment input.

Sediment Classifications and Definitions

Sediment within a stream can be classified into a variety of categories: turbidity, suspended sediment, bedload, deposited sediment, and wash load (Bash et al. 2001, pp. 3-4; Waters 1995, pp. 13-14). Sediment category definitions include:

- Turbidity - Optical property of water which results from the suspended and dissolved materials in the water. This causes light to be scattered rather than transmitted in straight lines. Turbidity is measured in nephelometric turbidity units (NTUs). Measurements of turbidity can quickly estimate the amount of sediment within a sample of water.
- Suspended sediment - Represents the actual measure of mineral and organic particles transported in the water column. Suspended sediment is measured in mg/L and is an

important measure of erosion, and is linked to the transport of nutrients, metals, and industrial and agricultural chemicals through the river system.

- Bedload - Consists of larger particles on the stream bottom that move by sliding, rolling, or saltating along the substrate surface. Bedload is measured in tons/day, or tons/year.
- Deposited sediment - The intermediate sized sediment particles that settle out of the water column in slack or slower moving water. Based on water velocity and turbulence, these intermediate size particles may be suspended sediment or bedload.
- Wash load - Finest particles in the suspended load that are continuously maintained in suspension by the flow turbulence. Therefore significant quantities are not deposited in the bed.

Suspended sediment, turbidity, and deposited sediment are not associated with specific particle sizes, as there will be considerable overlap depending on velocity, turbulence, and gradient (MacDonald et al. 1991, p. 98; Waters 1995, p. 14). Turbidity cannot always be correlated with suspended solid concentrations due to the effects of size, shape and refractive index of particles (Bash et al. 2001, p. 5). Turbidity and suspended sediment affect the light available for photosynthesis, visual capability of aquatic animals, gill abrasion, and physiology of fish. Suspended and deposited sediment affect the habitat available for macroinvertebrates, the quality of gravel for fish spawning, and the amount of habitat for fish rearing (Waters 1995, p. 14).

The size of particles within the stream is also important. The quantity of "fines" within a stream ecosystem is usually associated with the degree of fish population declines (Castro and Reckendorf 1995, p. 2). Particle diameters less than 6.4 mm are generally defined as "fines" (Bjornn et al. 1977, p. 1; Bjornn and Reiser 1991, p. 103; Castro and Reckendorf 1995, p. 2; Chapman 1988, p. 14; Hillman et al. 1987, p. 185; MBTSG 1998, p. 8; Rieman and McIntyre 1993, p. 6; Shepard et al. 1984, p. 148).

Biological Effects of Sediment on Salmonids

<u>Classification of Sediment Effects</u>

In the absence of detailed local information on population dynamics and habitat use, any increase in the proportion of fines in substrates should be considered a risk to the productivity of an environment and to the persistence of associated salmonid populations (Rieman and McIntyre 1993, p. 6). Specific effects of sediment on fish and their habitat can be put into three classes that include (Bash et al. 2001, p. 10; Newcombe and MacDonald 1991, pp. 72-73; Waters 1995, pp. 81-82)

Lethal: Direct mortality to any life stage, reduction in egg-to-fry survival, and loss of spawning or rearing habitat. These effects damage the capacity of salmonid to produce fish and sustain populations.

Sublethal: Reduction in feeding and growth rates, decrease in habitat quality, reduced tolerance to disease and toxicants, respiratory impairment, and physiological

stress. While not leading to immediate death, may produce mortalities and population decline over time.

Behavioral: Avoidance and distribution, homing and migration, and foraging and predation. Behavioral effects change the activity patterns or alter the kinds of activity usually associated with an unperturbed environment. Behavior effects may lead to immediate death or population decline or mortality over time.

Direct Effects

Gill trauma

High levels of suspended sediment and turbidity can result in direct mortality of fish by damaging and clogging gills (Curry and MacNeill 2004, p. 140). Fish gills are delicate and easily damaged by abrasive silt particles (Bash et al. 2001, p. 15). As sediment begins to accumulate in the gill filaments, fish excessively open and close their gills to expunge the silt. If irritation continues, mucus is produced to protect the gill surface, which may impede the circulation of water over the gills and interfere with fish respiration (Bash et al. 2001, p. 15). Gill flaring or coughing abruptly changes buccal cavity pressure and is a means of clearing the buccal cavity of sediment. Gill sediment accumulation may result when fish become too fatigued to continue clearing particles via the cough reflex (Servizi and Martens 1991, p. 495).

Fish are more susceptible to increased suspended sediment concentrations at different times of the year or in watersheds with naturally high sediment such as glaciated streams. Fish secrete protective mucous to clean the gills (Erman and Ligon 1985, p. 18). In glaciated systems or during winter and spring high flow conditions when sediment concentrations are naturally high, the secretion of mucous can keep gills clean of sediment. Protective mucous secretions are inadequate during the summer months, when natural sediment levels are low in a stream system. Consequently, sediment introduction at this time may increase the vulnerability of fish to stress and disease (Bash et al. 2001, p. 12).

Spawning, redds, eggs, and alevins

The effects of suspended sediment, deposited in a redd and potentially reducing water flow and smothering eggs or alevins or impeding fry emergence, are related to sediment particle sizes of the spawning habitat (Bjornn and Reiser 1991, p. 98). Sediment particle size determines the pore openings in the redd gravel. With small pore openings, more suspended sediments are deposited and water flow is reduced compared to large pore openings.

Survival of eggs is dependent on a continuous supply of well oxygenated water through the streambed gravels (Anderson et al. 1996, p. 13; Cederholm and Reid 1987, p. 384). Eggs and alevins are generally more susceptible to stress by suspended solids than are adults. Accelerated sedimentation can reduce the flow of water and, therefore, oxygen to eggs and alevins. This can decrease egg survival, decrease fry emergence rates (Bash et al. 2001, pp. 17-18; Cederholm and Reid 1987, p. 384; Chapman 1988, pp. 12-16), delay development of alevins (Everest et al. 1987, p. 113), reduce growth and cause premature hatching and emergence (Birtwell 1999, p. 19). Fry

delayed in their emergence are also less able to compete for environmental resources than fish that have undergone normal development and emergence (intra- or interspecific competition) (Everest et al. 1987, p. 113). Sedimentation fills the interstitial spaces and can prevent alevins from emerging from the gravel (Anderson et al. 1996, p. 13; Suttle et al. 2004, pp. 971-972).

Several studies have documented that fine sediment can reduce the reproductive success of salmonids. Natural egg-to-fry survival of coho salmon, sockeye and kokanee has been measured at 23 percent, 23 percent and 12 percent, respectively (Slaney et al. 1977, p. 33). Substrates containing 20 percent fines can reduce emergence success by 30-40 percent (MacDonald et al. 1991, p. 99). A decrease of 30 percent in mean egg-to-fry survival can be expected to reduce salmonid fry production to extremely low levels (Slaney et al. 1977, p. 33).

Indirect Effects

Macroinvertebrates

Sedimentation can have an effect on fish populations through impacts or alterations to the macroinvertebrate communities or populations (Anderson et al. 1996, pp. 14-15). Increased turbidity and suspended sediment can reduce primary productivity by decreasing light intensity and periphytic (attached) algal and other plant communities (Anderson et al. 1996, p. 14; Henley et al. 2000, p. 129; Suren and Jowett 2001, p. 726). This results in decreased macroinvertebrates that graze on the periphyton.

Sedimentation also alters the habitat for macroinvertebrates, changing the species density, diversity and structure of the area (Anderson et al. 1996, pp. 14-15; Reid and Anderson 1999, pp. 10-12; Shaw and Richardson 2001, p. 2220; Waters 1995, pp. 61-78). Certain groups of macroinvertebrates are favored by salmonids as food items. These include mayflies, caddisflies, and stoneflies. These species prefer large substrate particles in riffles and are negatively affected by fine sediment (Everest et al. 1987, p. 115; Waters 1995, p. 63). Increased sediment can affect macroinvertebrate habitat by filling of interstitial space and rendering attachment sites unsuitable. This may cause invertebrates to seek more favorable habitat (Rosenberg and Snow 1975, p. 70). With increasing fine sediment, invertebrate composition and density changes from available, preferred species (i.e., mayflies, caddisflies, and stoneflies) to non-preferred, more unavailable species (i.e., aquatic worms and other burrowing species) (Henley et al. 2000, pp. 126, 130; Reid and Anderson 1999, p. 10; Shaw and Richardson 2001, p. 2219; Suren and Jowett 2001, p. 726; Suttle et al. 2004, p. 971). The degree to which substrate particles are surrounded by fine material was found to have a strong correlation with macroinvertebrate abundance and composition (Birtwell 1999, p. 23). At an embeddedness of one-third, insect abundance can decline by about 50 percent, especially for riffle-inhabiting taxa (Waters 1995, p. 66).

Increased turbidity and suspended solids can affect macroinvertebrates in multiple ways through increased invertebrate drift, feeding impacts, and respiratory problems (Berry et al. 2003, pp. 8, 11; Cederholm and Reid 1987, p. 384; Shaw and Richardson 2001, p. 2218). The effect of turbidity on light transmission has been well documented and results in increased invertebrate drift (Birtwell 1999, pp. 21, 22; Waters 1995, p. 58). This may be a behavioral response associated with the night-active diel drift patterns of macroinvertebrates. While increased

turbidity results in increased macroinvertebrate drift, it is thought that the overall invertebrate populations would not fall below the point of severe depletion (Waters 1995, p. 59). Invertebrate drift is also an important mechanism in the repopulation, recolonization, or recovery of a macroinvertebrate community after a localized disturbance (Anderson et al. 1996, p. 15; Reid and Anderson 1999, pp. 11-12).

Increased suspended sediment can affect macroinvertebrates by abrasion of respiratory surface and interference with food uptake for filter-feeders (Anderson et al. 1996, p. 14; Berry et al. 2003, p. 11; Birtwell 1999, p. 21; Shaw and Richardson 2001, p. 2213; Suren and Jowett 2001, pp. 725-726). Increased suspended sediment levels tend to clog feeding structures and reduce feeding efficiencies, which results in reduced growth rates, increased stress, or death of the invertebrates (Newcombe and MacDonald 1991, p. 73). Invertebrates living in the substrate are also subject to scouring or abrasion which can damage respiratory organs (Bash et al. 2001, p. 25).

Feeding Efficiency

Increased turbidity and suspended sediment can affect a number of factors related to feeding for salmonids, including feeding rates, reaction distance, prey selection, and prey abundance (Barrett et al. 1992, pp. 437, 440; Bash et al. 2001, p. 21; Henley et al. 2000, p. 133). Changes in feeding behavior are primarily related to the reduction in visibility that occurs in turbid water. Effects on feeding ability are important as salmonids must meet energy demands to compete with other fishes for resources and to avoid predators. Reduced feeding efficiency would result in lower growth and fitness of salmonids (Barrett et al. 1992, p. 442; Sweka and Hartman 2001, p. 138).

Distance of prey capture and prey capture success both were found to decrease significantly when turbidity was increased (Berg and Northcote 1985, pp. 1414-1415; Sweka and Hartman 2001, p. 141; Zamor and Grossman 2007, pp. 168, 170, 174). Waters (1995, p. 83) states that loss of visual capability, leading to reduced feeding, is one of the major sublethal effects of high suspended sediment. Increases in turbidity were reported to decrease reactive distance and the percentage of prey captured (Bash et al. 2001, pp. 21-23; Klein 2003, pp. 1, 21; Sweka and Hartman 2001, p. 141). At 0 NTUs, 100 percent of the prey items were consumed; at 10 NTUs, fish frequently were unable to capture prey species; at 60 NTUs, only 35 percent of the prey items were captured. At 20 to 60 NTUs, significant delay in the response of fish to prey was observed (Bash et al. 2001, p. 22). Loss of visual capability and capture of prey leads to depressed growth and reproductive capability.

To compensate for reduced encounter rates with prey under turbid conditions, prey density must increase substantially or salmonids must increase their active searches for prey (Sweka and Hartman 2001, p. 144). Such an increase in activity and feeding rates under turbid conditions reduces net energy gain from each prey item consumed (Sweka and Hartman 2001, p. 144).

Sigler et al. (1984, p. 150) found that a reduction in growth occurred in steelhead and coho salmon when turbidity was as little as 25 NTUs. The slower growth was presumed to be from a reduced ability to feed; however, more complex mechanisms such as the quality of light may also affect feeding success rates. Redding et al. (1987, p. 742) found that suspended sediment

may inhibit normal feeding activity, as a result of a loss of visual ability or as an indirect consequence of increased stress.

Habitat Effects

Increases in sediment can alter fish habitat or the utilization of habitats by fish (Anderson et al. 1996, p. 12). The physical implications of sediment in streams include changes in water quality, degradation of spawning and rearing habitat, simplification and damage to habitat structure and complexity, loss of habitat, and decreased connectivity between habitats (Anderson et al. 1996, pp. 11-15; Bash et al. 2001, pp. 1, 12, 18, 30). Biological implications of this habitat damage include underutilization of stream habitat, abandonment of traditional spawning habitat, displacement of fish from their preferred habitat, and avoidance of habitat (Newcombe and Jensen 1996, p. 695).

As sediment enters a stream it is transported downstream under normal fluvial processes and deposited in areas of low shear stress (MacDonald and Ritland 1989, p. 21). These areas are usually behind obstructions, near banks (shallow water) or within interstitial spaces. This episodic filling of successive storage compartments continues in a cascading fashion downstream until the flow drops below the threshold required for movement or all pools have reached their storage capacities (MacDonald and Ritland 1989, p. 21). As sediment load increases, the stream compensates by geomorphologic changes in increased slope, increased channel width, decreased depths, and decreased flows (Castro and Reckendorf 1995, p. 21). These processes contribute to increased erosion and sediment deposition that further degrade salmonid habitat.

Loss of acceptable habitat and refugia, as well as decreased connectivity between habitats, reduces the carrying capacity of streams for salmonids (Bash et al. 2001, p. 30). This loss of habitat or exclusion of fish from their habitat, if timed inappropriately, could impact a fish population if the habitat within the affected stream reach is critical to the population during the period of the sediment release (Anderson et al. 1996, p. 12; Reid and Anderson 1999, p. 13). For example, if summer pool habitat used by adults as holding habitat prior to spawning is a limiting factor within a stream, increased sediment and reduced pool habitat during the summer can decrease the carrying capacity of the stream reach and decrease the fish population. In systems lacking adequate connectivity of habitats, fish may travel longer distances or use less desirable habitats, increasing biological demands and reducing their fitness.

The addition of fine sediment (less than 6.4 mm) to natural streams during summer decreased abundance of juvenile Chinook salmon in almost direct proportion to the amount of pool volume lost to fine sediment (Bjornn et al. 1977, p. 31). Similarly, the inverse relationship between fine sediment and densities of rearing Chinook salmon indicates the importance of winter habitat and high sediment loads (Bjornn et al. 1977, pp. 26, 38, 40). As fine sediments fill the interstitial spaces between the cobble substrate, juvenile Chinook salmon were forced to leave preferred habitat and to utilize cover that may be more susceptible to ice scouring, predation, and decreased food availability (Hillman et al. 1987, p. 194). Deposition of sediment on substrate may lower winter carrying capacity for salmonids (Shepard et al. 1984, p. 153). Food production in the form of aquatic invertebrates may also be reduced.

Although an avoidance response by fish to increased sediment may be an initial adaptive survival strategy, displacement from cover could be detrimental. It is possible that the consequences of fish moving from preferred habitat, to avoid increasing levels of suspended sediment, may not be beneficial if displacement is to sub-optimal habitat, because they may be stressed and more vulnerable to predation (Birtwell 1999, p. 12).

In addition to altering stream bed composition, anthropogenic input of sediment into a stream can change channel hydrology and geometry (Owens et al. 2005, pp. 694-695). Sediment release can reduce the depth of pools and riffle areas (Anderson et al. 1996, p. 12). This can reduce available fish habitat, decrease fish holding capacity, and decrease fish populations (Anderson et al. 1996, pp. 12, 14).

Physiological Effects

Sublethal levels of suspended sediment may cause undue physiological stress on fish, which may reduce the ability of the fish to perform vital functions (Cederholm and Reid 1987, pp. 388, 390). Stress is defined as a condition perceived by an organism which threatens a biological function of the organism, and a set of physiological and behavioral responses is mounted to counteract the condition (Overli 2001, p. 7). A stressor is any anthropogenic or natural environmental change severe enough to require a physiological response on the part of a fish, population, or ecosystem (Anderson et al. 1996, pp. 5-6; Jacobson et al. 2003, p. 2; USEPA 2001, pp. 1-2). At the individual level, stress may affect physiological systems, reduce growth, increase disease, and reduce the individual's ability to tolerate additional stress (Anderson et al. 1996, p. 7; Bash et al. 2001, p. 17). At the population level, the effects of stress may include reduced spawning success, increased larval mortality, and reduced recruitment to succeeding life stages and, therefore, overall population declines (Bash et al. 2001, p. 17).

Upon encountering a stressor, the fish responds through a series of chemical releases in its body. These primary chemical and hormonal releases include catecholamine (e.g. epinephrine, norepinehprine) in the circulatory system, corticosteroids (e.g. cortisol) from the interregnal tissue, and hypothalamic activation of the pituitary gland (Barton 2002, p. 517; Davis 2006, p. 116; Gregory and Wood 1999, p. 286; Schreck et al. 2001, p. 5). Primary chemical releases result in secondary releases or changes in plasma, glucose, tissue ion, metabolite levels, and hematological features. These secondary responses relate to physiological adjustments in metabolism, respiration, immune and cellular function (Barton 2002, p. 517; Haukenes and Buck 2006, p. 385; Mazeaud et al. 1977, p. 201). After secondary responses, continued stress results in tertiary stress responses which affect whole-animal performance such as changes in growth, condition, resistance to disease, metabolic scope for activity, behavior, and ultimately survival (Barton 2002, p. 517; Pickering et al. 1982, p. 229; Portz et al. 2006, pp. 126-127).

Stress in a fish occurs when the homeostatic or stabilizing process in the organism exceed the capability of the organism to compensate for the biotic or abiotic challenge (Anderson et al. 1996, p. 5). The response to a stressor is an adaptive mechanism that allows the fish to cope with the real or perceived stressor in order to maintain its normal or homeostatic state (Barton 2002, p. 517). Acclimation to a stressor can occur if compensatory physiological responses by the fish are able to re-establish a satisfactory relationship between the changed environment and the

organism (Anderson et al. 1996, p. 5). The ability of an individual fish to acclimate or tolerate the stress will depend on the severity of the stress and the physiological limits of the organism (Anderson et al. 1996, p. 5). In a natural system, fish are exposed to multiple chemical and physical stressors which can combine to cause adverse effects (Berry et al. 2003, p. 4). The chemical releases from each stressor results in a cumulative or additive response (Barton et al. 1986, pp. 245, 247; Cobleigh 2003, pp. 16, 39, 55; Milston et al. 2006, p. 1172; USEPA 2001, pp. 3-25).

Stress in fish results in extra cost and energy demands. Elevated oxygen consumption and increased metabolic rate result from the reallocation of energy to cope with the stress (Barton and Schreck 1987, pp. 259-260; Contreras-Sanchez et al. 1998, pp. 439, 444; McCormick et al. 1998, pp. 222, 231). An approximate 25 percent increase in metabolic cost, over standard metabolism requirements, is needed to compensate for a perceived stress (Barton and Schreck 1987, p. 260; Davis 2006, p. 116). Stressed fish would thus have less energy available for other life functions such as seawater adaptation, disease resistance, reproduction, or swimming stamina (Barton and Schreck 1987, p. 261; Contreras-Sanchez et al. 1998, p. 444).

Tolerance to suspended sediment may be the net result of a combination of physical and physiological factors related to oxygen availability and uptake by fish (Servizi and Martens 1991, p. 497). The energy needed to perform repeated coughing (see Gill trauma section) increases metabolic oxygen demand. Metabolic oxygen demand is related to water temperature. As temperatures increase, so does metabolic oxygen demand, but concentrations of oxygen available in the water decreases. Therefore, a fish's tolerance to suspended sediment may be primarily related to the capacity of the fish to perform work associated with the cough reflex. However, as sediment increases, fish have less capability to do work, and therefore less tolerance for suspended sediment (Servizi and Martens 1991, p. 497).

Once exposed to a stressor, the primary chemical releases can take one-half to twenty-four hours to peak (Barton 2002, p. 520; Quigley and Hinch 2006, p. 437; Schreck 1981, p. 298). Recovery or return of the primary chemical release to normal or resting levels can take two hours to two weeks (Mazeaud et al. 1977, pp. 205-206; Schreck et al. 2001, p. 313). In a study of handling stress, chemical release of cortisol peaked at two hours and returned to normal in four hours. However, complete recovery took 2 weeks (Pickering et al. 1982, pp. 236, 241). Fish exposed to two or more stresses require longer recovery times than fish exposed only to one stressor indicating the cumulative effects of stress (Sigismondi and Weber 1988, pp. 198-199).

Redding el al. (1987, pp. 740-741) observed higher mortality in young steelhead trout exposed to a combination of suspended sediment (2500 mg/L) and a bacteria pathogen, than when exposed to the bacteria alone. Physiological stress in fishes may decrease immunological competence, growth, and reproductive success (Bash et al. 2001, p. 16).

Behavioral effects

Increased turbidity and suspended sediment may result in behavior changes in salmonids. These changes are the first effects evoked from increased levels of turbidity and suspended sediment (Anderson et al. 1996, p. 6). These behavioral changes include avoidance of habitat, reduction in

feeding, increased activity, redistribution and migration to other habitats and locations, disruption of territoriality, and altered homing (Anderson et al. 1996, p. 6; Bash et al. 2001, pp. 19-25; Suttle et al. 2004, p. 971). Many behavioral effects result from changes in stream habitat (see Habitat effects section). As suspended sediment concentration increases, habitat may be lost which results in abandonment and avoidance of preferred habitat. Stream reach emigration is a bioenergetic demand that may affect the growth or reproductive success of the individual fish (Bash et al. 2001, p. 12). Pulses of sediment result in downstream migration of fish, which disrupts social structures, causes downstream displacement of other fish and increases intraspecific aggression (Bash et al. 2001, pp. 12, 20; McLeay et al. 1987, pp. 670-671; Suttle et al. 2004, p. 971). Loss of territoriality and the breakdown of social structure can lead to secondary effects of decreased growth and feeding rates, which may lead to mortality (Bash et al. 2001, p. 20; Berg and Northcote 1985, p. 1416).

Downstream migration by salmonids provide access to more prey, better protection from avian and terrestrial predators, and alleviates potential intraspecific competition or cannibalism in rearing areas (MBTSG 1998, p. 13). Benefits of migration from tributary rearing areas to larger rivers or estuaries may be increased growth potential. Increased sedimentation may result in premature or early migration of both juveniles and adults or avoidance of habitat and migration of nonmigratory resident fish.

High turbidity may delay migration back to spawning sites, although turbidity alone does not seem to affect homing. Delays in spawning migration and associated energy expenditure may reduce spawning success and therefore population size (Bash et al. 2001, p. 29).

LITERATURE CITED

Ahearn, D.S. 2002. The biochemistry of glacial and spring-fed streams in the Copper River Watershed, Alaska. *In* J. Mount, P. Moyle, and S. Yarnell, eds. Glacial and periglacial processes as hydrogeomorphic and ecological drivers in high-latitude watersheds, , Davis, CA.

Anderson, P.G., B.R. Taylor, and G.C. Balch. 1996. Quantifying the effects of sediment release on fish and their habitats. Fisheries and Oceans, Canada, Canadian Manuscript Report of Fisheries and Aquatic Sciences 2346.

Barrett, J.C., G.D. Grossman, and J. Rosenfeld. 1992. Turbidity-induced changes in reactive distance of rainbow trout. Transactions of the American Fisheries Society 121:437-443.

Barton, B.A. 2002. Stress in fishes: a diversity of responses with particular reference to changes in circulating corticosteroids. Integrated and Comparative Biology 42:517-525.

Barton, B.A., and C.B. Schreck. 1987. Metabolic cost of acute physical stress in juvenile steelhead. Transactions of the American Fisheries Society 116:357-363.

Barton, B.A., C.B. Schreck, and L.D. Barton. 1986. Multiple acute disturbances evoke cumulative physiological stress responses in juvenile Chinook salmon. Transactions of the American Fisheries Society 115:245-251.

Bash, J., C.H. Berman, and S. Bolton. 2001. Effects of turbidity and suspended solids on salmonids. Center for Streamside Studies, University of Washington, Seattle, WA, November 2001. 72 pp.

Berg, L., and T.G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behavior in juvenile coho salmon (*Oncorhynchus kisutch*) following short-term pulses of suspended sediment. Canadian Journal of Fisheries and Aquatic Sciences 42:1410-1417.

Berry, W., N.I. Rubinstein, B. Melzian, and B. Hill. 2003. The biological effects of suspended and bedded sediment in aquatic systems: a review. USEPA, Office of Research and Development, National Health and Environmental Effects Laboratory, Narragansett, Rhode Island.

Birtwell, I.K. 1999. The effects of sediment on fish and their habitat. Fisheries & Oceans Canada, Canadian Stock Assessment Secretariat Research Document 99/139, West Vancouver, British Columbia. 34 pp.

Bjornn, T.C., M.A. Brusven, M.P. Molnau, J.H. Milligan, R.A. Klamt, E. Chacho, and C. Schaye. 1977. Transport of granitic sediment in streams and its effects on insects and fish. University of Idaho, Idaho Cooperative Fisheries Research Unit, Research Technical Completion Project B-036-IDA, Bulletin 17, Moscow, Idaho. 43 pp.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83-138 *In* W.R. Meehan, ed. Influences of forest and rangeland management on salmonid fishes and their habitats, American Fisheries Society Special Publication 19.

Castro, J., and F. Reckendorf. 1995. RCA III: Effects of sediment on the aquatic environment; potential NRCS actions to improve aquatic habitat. Natural Resources Conservation Service, Oregon State University, Department of Geosciences.

Cederholm, C.J., and L.M. Reid. 1987. Impact of forest management on coho salmon (*Oncorhynchus kisutch*) populations of the Clearwater River, Washington: A project summary. Pages 373-398 *In* E.O. Salo, and T.W. Cundy, eds. Streamside management: Forestry and fishery interactions. University of Washington Institute of Forest Resource Contribution 57.

Chapman, D.W. 1988. Critical-review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society 117(1):1-21.

Cobleigh, M.M. 2003. Stress, growth, and survival of juvenile Chinook salmon. Master's Thesis. University of Washington, School of Aquatic and Fisheries Science, Seattle, WA.

Contreras-Sanchez, W., C.B. Schreck, M.S. Fitzpatrick, and C.B. Pereira. 1998. Effects of stress on the reproduction performance of rainbow trout (*Oncorhynchus mykiss*). Biology of reproduction 58:439-447.

Curry, R.A., and W.S. MacNeill. 2004. Population-level responses to sediment during early life in brook trout. Journal of the North American Benthological Society 23:140-150.

Davis, K.B. 2006. Management of physiological stress in finfish aquaculture. North American Journal of Aquaculture 68:116-121.

Erman, D.C., and F.K. Ligon. 1985. The response of algal communities in streams of the Jackson Demonstration State Forest to timber harvest activities. State of California, Department of Forestry. 49 pp.

Everest, F.H., R.L. Beschta, J.C. Scrivener, K.V. Koski, J.R. Sedell, and C.J. Cederholm. 1987. Fine sediment and salmonid production: A paradox. Pages 98-142 *In* E.O. Salo, and T.W. Cundy, eds. Streamside management: Forestry and fishery interactions, University of Washington Institute of Forest Resources Contribution 57.

FAO (Food and Agriculture Organization of the United Nations). 1976. Indices for measuring responses of aquatic ecological systems to various human influences. Food and Agricultural Organization of the United Nations, Fisheries Technical Paper 151, Rome, Italy.

Galbraith, R.V., E.A. MacIsaac, J.S. MacDonald, and A.P. Farrell. 2006. The effect of suspended sediment on fertilization success in sockeye (*Oncorhynchus nerka*) and coho (*Oncorhynchus kisutch*) salmon. Canadian Journal of Fish and Aquatic Science 63:2487-2494.

Gregory, T.R., and C.M. Wood. 1999. The effects of chronic plasma cortisol elevation on the feeding behaviour, growth, competitive ability, and swimming performance of juvenile rainbow trout. Physiological and Biochemical Zoology 72(3):286-295.

Haukenes, A.H., and C.L. Buck. 2006. Time course of osmoregulatory, metabolic, and endocrine stress responses of Pacific halibut following a 30-min air exposure. Journal of Applied Ichthyology 22:382-387.

Henley, W.F., M.A. Patterson, R.J. Neves, and A.D. Lemly. 2000. Effects of sedimentation and turbidity on lotic food webs: a concise review from natural resource managers. Reviews in Fisheries Science 8(2):125-139.

Hillman, T.W., J.S. Griffith, and W.S. Platts. 1987. Summer and winter habitat selection by juvenile Chinook salmon in a highly sedimented Idaho stream. Transactions of the American Fisheries Society 116:185-195.

Jacobson, K.C., M.R. Arkoosh, A.N. Kagley, E.R. Clemons, T.K. Collier, and E. Casillas. 2003. Cumulative effects of natural and anthropogenic stress on immune function and disease resistance in juvenile Chinook salmon. Journal of Aquatic Animal Health 15:1-12.

Johnston, F.D., J.R. Post, C.J. Mushens, J.D. Stelfox, A.J. Paul, and B. Lajeuness. 2007. The demography of recovery of an overexploited bull trout, *Salvelinus confluentus,* population. Canadian Journal of Fish and Aquatic Science 64:113-126.

Klein, R. 2003. Duration of turbidity and suspended sediment transport in salmonid-bearing streams, north coastal California. U.S. Environmental Protection Agency, Region IX, San Francisco, CA, March 2003.

Lake, R.G., and S.G. Hinch. 1999. Acute effects of suspended sediment angularity on juvenile coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 56:862-867.

MacDonald, A., and K.W. Ritland. 1989. Sediment dynamics in type 4 and 5 waters: A review and synthesis. PTI Environmental Services, Timber Fish and Wildlife. TFW-012-89-002, Bellevue, Washington.

MacDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. U.S. Environmental Protection Agency, Region 10. University of Washington, EPA 90/6-91-001, Seattle, WA. 166 pp.

Mazeaud, M.M., F. Mazeaud, and E.M. Donaldson. 1977. Primary and secondary effects of stress in fish: some new data with a general review. Transactions of the American Fisheries Society 106(3):201-212.

MBTSG (The Montana Bull Trout Scientific Group). 1998. The relationship between land management activities and habitat requirements of bull trout. Montana Fish, Wildlife, and Parks, Helena, MT, May 1998. 77 pp.

McCormick, S.D., J.M. Shripton, J.B. Carey, M.F. O'Dea, K.E. Sloan, S. Moriyama, and B.T. Björnsson. 1998. Repeated acute stress reduces growth rate of Atlantic salmon parr and alters plasma levels of growth hormone, insulin-like growth factor I and cortisol. Aquaculture 168:221-235.

McLeay, D.J., I.K. Birtwell, G.F. Hartman, and G.L. Ennis. 1987. Responses of arctic grayling (*Thymallus arcticus*) to acute and prolonged exposure to Yukon placer mining sediment. Canadian Journal of Fisheries and Aquatic Sciences 44(3):658-673.

Milston, R.H., M.W. Davis, S.J. Parker, B.L. Olla, S. Clements, and C.B. Schreck. 2006. Characterization of the physiological stress response in lingcod. Transactions of the American Fisheries Society 135:1165-1174.

Newcombe, C.P. 2003. Impact assessment model for clear water fishes exposed to excessively cloudy water. Journal of the American Water Resources Association 39(3):529-544.

Newcombe, C.P., and J.O.T. Jensen. 1996. Channel suspended sediment and fisheries: synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16(4):693-727.

Newcombe, C.P., and D.D. MacDonald. 1991. Effects of Suspended Sediments on Aquatic Ecosystems. North American Journal of Fisheries Management 11(1):72-82.

Overli, O. 2001. Behavioural and neuroendocrine effects of stress in salmonid fishes. Acta Universitatis Upsaliensis. Comprehensive Summaries of Uppsala. Dissertations from the Faculty of Science and Technology 623, ISBN 91-554-5007-5, Uppsala, Sweden. 79 pp.

Owens, P.N., R.J. Batalla, A.J. Collins, B. Gomez, D.M. Hicks, A.J. Horowitz, G.M. Konkolf, M. Marden, M.M. Page, D.H. Peacock, E.L. Petticrew, W. Salomons, and N.A. Trustrum. 2005. Fine-grained sediment in river systems: environmental significance and management issues. River Research and Applications 21:693-717.

Pickering, A.D., T.G. Pottinger, and P. Christie. 1982. Recovery of the brown trout, *Salmo trutta* L., from acute handling stress: a time-course study. Journal of Fish Biology 20:229-244.

Portz, D.E., C.M. Woodley, and J.J. Cech. 2006. Stress-associated impacts of short-term holding on fishes. Reviews in Fish Biology and Fisheries 16:125-170.

Quigley, J.T., and S.G. Hinch. 2006. Effects of rapid experimental temperature increases on acute physiological stress and behaviour of stream dwelling juvenile Chinook salmon. Journal of Thermal Biology 31:429-441.

Redding, J.M., C.B. Schreck, and F.H. Everest. 1987. Physiological effects on coho salmon and steelhead of exposure to suspended solids. Transactions of the American Fisheries Society 116(5):737-744.

Reid, S., and P.G. Anderson. 1999. Effects of sediment released during open-cut pipeline water crossings. Canadian Water Resources Journal 24:23-39.

Rhodes, J.J., D.A. McCullough, and F.A. Espinosa Jr. 1994. A coarse screening process for potential application in ESA consultations. Columbia River Inter-Tribal Fish Commission, Technical Report 94-4, Portland, Oregon. 126 pp.

Rieman, B.E., and J.D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, General Technical Report INT-302, Ogden, Utah. 38 pp.

Rosenberg, D.M., and N.B. Snow. 1975. A design for environmental impact studies with special reference to sedimentation in aquatic systems of the Mackenzie and Porcupine River drainages. Pages 65-78 *In* Proceedings of the circumpolar conference on northern ecology, September 15-18, 1975, National Research Council of Canada, Ottawa, Ontario. 12 pp.

Schreck, C.B. 1981. Stress and compensation in teleostean fishes: response to social and physical factors. Pages 295-321 *In* A.D. Pickering, ed. Stress and Fish, Academic Press, London; New York.

Schreck, C.B., W. Contreras-Sanchez, and M.S. Fitzpatrick. 2001. Effects of stress on fish reproduction, gamete quality, and progeny. Aquaculture 197:3-24.

Servizi, J.A., and D.W. Martens. 1991. Effect of temperature, season, and fish size on acute lethality of suspended sediments to coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 48(3):493-497.

Shaw, E.A., and J.S. Richardson. 2001. Direct and indirect effects of sediment pulse duration on stream invertebrate assemblages and rainbow trout (*Oncorhynchus mykiss*) growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:2213-2221.

Shepard, B.B., S.A. Leathe, T.M. Weaver, and M.D. Enk. 1984. Monitoring levels of fine sediment within tributaries to Flathead Lake, and impacts of fine sediment on Bull trout recruitment. *In* Proceedings of the Wild Trout III Symposium, September 24 - 25, 1984, Mammoth Hot Springs, Yellowstone National Park, Wyoming. 11 pp.

Sigismondi, L.A., and L.J. Weber. 1988. Changes in avoidance response time of juvenile Chinook salmon exposed to multiple acute handling stresses. Transactions of the American Fisheries Society 117(2):196-201.

Sigler, J.W., T.C. Bjornn, and F.H. Everest. 1984. Effects of chronic turbidity on density and growth of steelheads and coho salmon. Transactions of the American Fisheries Society 113:142-150.

Skinner, B.J., and S.C. Porter. 2000. The dynamic earth: an introduction to physical geology, 4th ed. John Wiley & Sons, Inc, New York. 575 pp.

Slaney, P.A., T.G. Halsey, and A.F. Tautz. 1977. Effects of forest harvesting practices on spawning habitat of stream salmonids in the Centennial Creek watershed, British Columbia. British Columbia Ministry of Recreation and Conservation, Fish and Wildlife Branch, Fisheries Management Report 73, Victoria, British Columbia.

Suren, A.M., and I.G. Jowett. 2001. Effects of deposited sediment on invertebrate drift: an experimental study. New Zealand Journal of Marine and Freshwater Research 35:725-537.

Suttle, K.B., M.E. Power, J.M. Levine, and C. McNeely. 2004. How fine sediment in riverbeds impairs growth and survival of juvenile salmonids. Ecological Applications 14(4):969-974.

Sweka, J.A., and K.J. Hartman. 2001. Influence of turbidity on brook trout reactive distance and foraging success. Transactions of the American Fisheries Society 130:138-146.

Uehlinger, U.K., K. Tockner, and F. Malard. 2002. Ecological windows in glacial stream ecosystems. EAWAG News 54e:20-21.

USEPA. 2001. Temperature interaction: Issue paper 4 prepared as part of EPA Region 10 temperature and water quality criteria guidance development project. EPA-910-D-01-004.

USFWS. 1998. Bull trout interim conservation guidance. Western Washington Fish and Wildlife Office, Lacey, Washington. 47 pp.

Vondracek, B., J.K.H. Zimmerman, and J.V. Westra. 2003. Setting an effective TMDL: sediment loading and effects of suspended sediment on fish. Journal of the American Water Resources Association 39(5):1005-1015.

Waters, T.F. 1995. Sediment in streams: Sources, biological effects, and control. American Fisheries Society, Monograph 7, Bethesda, Maryland.

Watts, C.D., P.S. Naden, D. Cooper, and B. Gannon. 2003. Application of a regional procedure to assess the risk to fish from high sediment concentrations. The Science of the Total Environment 314-316:551-565.

Zamor, R.M., and G.D. Grossman. 2007. Turbidity affects foraging success of drift-feeding rosyside dace. Transactions of the American Fisheries Society 136:167-176.

APPENDIX B
MARINE MAMMAL MONITORING PLAN
From City of Seattle's IHA Application

City of Seattle

Pier 62 Project

APPENDIX A
MARINE MAMMAL MONITORING PLAN

Revised May 2017

Marine Mammal Monitoring Plan for the Pier 62 Project

May 23, 2017

Submitted by:

City of Seattle
Department of Transportation
700 5th Avenue, Suite 3900
Seattle WA 98124

Prepared by:

Anchor QEA, LLC

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS, ABBREVIATIONS AND DEFINITIONS

dB	decibel
Hz	hertz
kHz	kilohertz
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
RMS	root mean square
SEL	sound exposure level

SECTION 1. INTRODUCTION

The proposed monitoring plan for the Pier 62 Project includes a construction monitoring protocol as well as guidelines for construction activities associated with pile installation and removal. Monitoring would occur by observing construction activities and the surrounding marine environment for signs of marine mammals and/or potential threats to marine mammals, as well as measuring underwater noise produced by in-water, pile-related activities. This Monitoring Plan is intended to retaining enough flexibility for the monitors to use their best scientific judgment for unforeseen events that will allow for optimal protection of marine mammals.

1.1 CONSTRUCTION MONITORING

For the Pier 62 Project, monitoring of in-water, pile-related construction would be accomplished by land-based, protected-species observers. For work with a vibratory hammer, three monitors would be required. One monitor would be located at the construction site to survey the nearshore environment immediately surrounding active pile-related construction, and would be in close contact with construction personnel. The other two monitors would be located on the north and south entrances to Elliott Bay. All three observers would monitor the designated Exclusion and Level B Harassment Zones, which are listed in Table 1 and shown on Figures 1 through 3.

TABLE 1. SUMMARY OF EXCLUSION ZONE THRESHOLDS

Hearing Group	Exclusion Zone Thresholds[1]	Pile Driver Type	Pile Type
Low-frequency cetaceans	17.4 meters	Vibratory	Timber extraction
	504.8 meters	Vibratory	Steel pile
	382.9 meters	Impact	Steel pile
Mid-frequency cetaceans	1.5 meters	Vibratory	Timber extraction
	44.7 meters	Vibratory	Steel pile
	13.6 meters	Impact	Steel pile
High-frequency cetaceans	25.7 meters	Vibratory	Timber extraction
	746.4 meters	Vibratory	Steel pile
	456.1 meters	Impact	Steel pile
Phocid pinnipeds	10.6 meters	Vibratory	Timber extraction
	306.8 meters	Vibratory	Steel pile
	204.9 meters	Impact	Steel pile
Otariid pinnipeds	0.7 meters	Vibratory	Timber extraction
	21.5 meters	Vibratory	Steel pile
	14.9 meters	Impact	Steel pile

Note:

1. Radius distance from point-source, pile-related noise. Stop-work order will be issued if threshold is crossed.

When pile driving is limited to installation with an impact hammer, one monitor, based at or near the construction site, will conduct monitoring. In the case where visibility becomes limited, additional land-based monitors and/or boat-based monitors may be deployed.

Acoustic monitoring would also occur during in-water pile driving and removal activities to document actual sound levels generated. Details regarding these aspects are discussed in the following sections.

1.1.1 Exclusion Zone Monitoring

Proposed Exclusion Zone Thresholds are provided in Table 1. Each Exclusion Zone Threshold and Level B harassment zone was determined by using the Practical Spreading Model for the pile types proposed; ambient acoustic data for Elliott Bay (WSDOT 2011); hydroacoustic monitoring for the Elliott Bay Seawall Project Seasons 1, 2, 3, and 4 (Anchor QEA 2014, 2015, 2016, and 2017); and the National Oceanic and Atmospheric Administration's 2016 guidance (NOAA 2016). All thresholds represent radii distances from the point-source, pile-related work, and each is specific to marine mammal hearing groups. In addition, the Exclusion Zones and Level B Harassment Zones are specific to the type of pile activity (installation via impact or vibratory hammer, removal via vibratory hammer), and pile type (steel or timber).

Exclusion Zones, which have been established by hearing group per NOAA's 2016 guidance, are intended to provide a physical threshold that, when crossed by a given marine mammal species, will trigger a stop- work order for in-water pile installation or removal (NOAA 2016). In the event that a stop-work order is triggered, the observed marine mammal(s) will be closely monitored while it remains in or near the Exclusion Zone, and only when it moves well outside of the Exclusion Zone or has not been observed for at least 15 minutes for pinnipeds and 30 minutes for whale, will the lead monitor allow work to recommence. It will be up to the best scientific judgment of the monitor(s) observing the marine mammal to determine when it has moved far enough away from the Exclusion Zone.

All marine mammals that are near an applicable Exclusion Zone Threshold will be closely monitored, and every precaution will be taken to ensure they are not harmed in any way. If an individual marine mammal shows signs of distress or unexpected behavior, even while they are well outside of an applicable Exclusion Zone Threshold, a stop-work order will be issued and further consultation will be made with NOAA/National Marine Fisheries Service (NMFS).

Figure 1. Exclusion and Level B Harassment Zones for Vibratory Pile Removal

Figures to be finalized when the IHA is issued.

Figure 2. Exclusion and Level B Harassment Zones for Impact Pile Driving

Figures to be finalized when the IHA is issued.

Figure 3. Exclusion and Level B Harassment Zones for Vibratory Pile Driving

Figures to be finalized when the IHA is issued.

1.1.2 Stop-work Order Protocol

When a marine mammal is observed approaching the applicable Exclusion Zones (see Table 1 and Figures 1 through 3), the monitor(s) will immediately notify the construction manager of the direction of travel and distance of the marine mammal relative to the Exclusion Zone. A stop-work order would be immediately issued if a monitor observes a marine mammal clearly crossing an applicable Exclusion Zone, regardless of observed marine mammal behavior. In response, the construction manager will immediately require the operator of the vibratory or impact hammer to stop work.

Following issuance of a stop-work order, the marine mammal will be closely monitored and updates of location and behavior will be provided to the construction manager at appropriate intervals, likely less than 15 minutes apart. The marine mammal will continue to be monitored while it is within the Exclusion Zone until it has clearly moved out of and away from the threshold, has not been observed for at least 15 minutes for pinnipeds or 30 minutes for whales, or when the end of the work day is reached.

Work will resume after the marine mammal monitor(s) has notified the construction manager that the marine mammal has moved outside of, and is headed away from, the Exclusion Zone or has not been observed for at least 15 minutes for pinnipeds or 30 minutes for whales. At times, unanticipated scenarios may be encountered by the marine mammal monitors, who will use their best scientific judgment to make conservative decisions to ensure no marine mammal will be harmed by in-water operation of a vibratory or impact hammer.

1.1.3 Level B Behavioral Harassment Zones

In addition to monitoring the Exclusion Zones described above, protected-species observers will also monitor the Level B Harassment Zones. These zones vary by activity but are the same for all hearing groups. Table 2 provides a summary of the Level B Harassment Zones for each activity. The Level B Harassment Zone starts at the activity-specific Exclusion Zone for the relevant hearing group and extends in a radial arc out to the distance indicated in the table. The distance to the Level B Harassment Zone for vibratory installation of steel piles stops short of the modeled distance due to intervening land masses.

TABLE 2. SUMMARY OF LEVEL B HARASSMENT ZONES

Pile Type and Activity	Pile Driver Type	Distance to Level B Harassment Zone
Timber extraction	Vibratory	1,865 meters
Steel pile installation	Impact	1,201 meters
	Vibratory	54,177 meters

Within this monitoring area, the cumulative daily number of "take" will be documented throughout each pile-related work day. All sightings of marine mammals will be documented by the monitors on a Marine mammal sighting form, which is described in Section 1.3.1. A take

will be documented for each individual marine mammal no more than once in a 24-hour period. The monitors will keep an accurate take count of marine mammals sighted within their applicable Level B Harassment Zone, document each take on the sighting form, and notify the construction crew and other appropriate staff if any marine mammal has the potential to cross an applicable Exclusion Zone Threshold. Once a marine mammal is within the area of potential effects, the observers will track its movements and document its behaviors until it moves well out of the area.

1.2 ESTIMATED TAKE

Table 3 provides the number of takes for each marine mammal species requested by the City of Seattle for the Pier 62 Project. If the authorized total take for any particular species is reached at any point prior to the completion of in-water pile driving and/or removal, NOAA/NMFS will be immediately notified that the take has been reached and will be consulted for further guidance.

TABLE 3. REQUESTED INCIDENTAL LEVEL B HARASSMENT TAKE

Marine Mammal Species	Stock Size	Total Take Requested	Take, as Percentage of Total Stock
Pacific harbor seal (*Phoca vitulina*)	11,036	2,207	20
Northern elephant seal (*Mirounga angustirostris*)	81,368	1	Less than 1
California sea lion (*Zalophus californianus*)	296,750	949	Less than 1
Steller sea lion (*Eumetopias jubatus*)	67,290	187	Less than 1
Harbor porpoise (*Phocoena phocoena*)	10,682	2,136	20
Dall's porpoise (*Phocoenoides dalli*)	42,000	201	Less than 1
Long-beaked common dolphin (*Dephinus capensis)*	107,016	20	Less than 1
Southern resident killer whale DPS (*Orcinus orca*)	78	16	20
Transient killer whale (*Orcinus orca*)	243	48	20
Humpback whale (*Megaptera novaengliae*)	1,876	5	Less than 1
Gray whale (*Eschrichtius robustus*)	20,990	4	Less than 1
Minke whale (*Balaenoptera acutorostrata*)	202	2	Less than 1

1.1.1 Marine Mammal Monitoring Protocol

Marine mammal monitors would be deployed in strategic locations around the area of potential effects at all times during in-water pile driving and removal. Monitors would be based on land and positioned as shown in Figure 3. In the case where visibility becomes limited, additional land-based monitors and/or boat-based monitors may be deployed.

It is anticipated that one monitor, located at or near the construction site, would be able to sufficiently monitor the Level B Harassment and Exclusion Zones during impact installation of steel piles (Figure 2). However, three land-based observers would be required at all times during vibratory pile driving or removal (Figures 1 and 3). Collectively, monitors positioned at these locations would be able to monitor the outer Exclusion Zone and surrounding marine environment at all times during pile-related construction. These zones would vary depending on the type of pile and method of installation.

One monitor will be stationed at the construction site near the activity. Two additional monitors would be stationed at designated viewpoints on the north and south entrance of Elliott Bay, likely at Hamilton Viewpoint Park (Alki Point) and at West 32nd Avenue (city pump station), providing them broad, unobstructed view-sheds. During vibratory pile installation, the monitor stationed at Alki Point will walk between the east and west sides of the point so that the full Level B Harassment Zone can be viewed.

Each marine mammal monitor will be tasked with continuously scanning their view-shed within the zone of influence, documenting all marine mammals and, if seen, closely tracking their behaviors and locations, and communicating their observations to the rest of the monitoring crew. Proper coordination between the team of monitors and the construction manager will be facilitated by a designated monitoring coordinator who will establish coordination details each morning prior to the start of construction, and strictly maintain them throughout the construction day. Monitors will have a clear understanding of the location of various zones that pertain to each type of pile activity and the associated marine mammal hearing groups, and will continually coordinate and update each other as well as other crew members, as appropriate. Communication will be primarily via cellular phone. Each monitor will have a list of contact phone numbers, including for the monitoring coordinator, construction manager, and other management and staff.

Coordination between monitors and construction contractors would occur at least once each day prior to the start of work. This coordination would include a review of the pile-related work schedule and any marine mammal issues that could potentially occur. Other details provided to the monitors would include construction location, number and type of piles, timing, whether work would be pile installation or removal, and the type of hammer to be used. Any changes in pile-related work schedule will be conveyed to the monitors at least 30 minutes prior to their implementation, when possible.

Marine mammal monitoring will begin at least 30 minutes prior to the start of all pile driving and removal each day, and will continue at all times during active pile driving and removal. If necessary due to the presence of a marine mammal within or near the Exclusion Zone at the end of the pile-driving or removal shift, marine mammal monitoring will continue for up to 30

minutes following construction. If visibility precludes monitors from viewing their designated view-shed (due to fog or poor lighting), then pile-driving activities would not be allowed or alternate methods of monitoring must be employed (i.e., boat-based monitoring). Monitors will be continually updated on pile-related construction activities in a manner that would allow them to make adjustments to provide accurate and appropriate marine mammal observations.

All monitors will be trained protected-species observers with good eyesight and identification skills. Monitors will have received NOAA-approved training that covers detection, identification, and distance estimation (i.e., estimating the distance a marine mammal is from an observer) of all marine mammal species potentially found in and around Elliott Bay. Each monitor must pass an identification test conducted at the training. Each will have the experience and ability to conduct field observations and collect data according to this protocol. They will be experienced with directional orienteering, using binoculars and spotting scopes, efficiently accessing and referencing marine mammal identification materials, understanding safety protocol, and writing field notes and entering data into the field datasheets (Attachment A). Each monitor will be properly equipped with necessary gear during their shift, including binoculars, field guides, compass, cellular phone, and back-up power.

Each monitor would work, on average, eight to 10 daylight hours per day and would be relieved by a new monitor if pile-related activities occur over a longer day or fatigue and/or lack of preparedness begins to decrease ability to detect marine mammals. If necessary, the number of monitors would be increased and/or their positions would be changed to ensure full visibility of the area of potential effects and to ensure early sighting of any marine mammal that enters the area. Monitors shall have no other responsibilities while making observations.

A comprehensive marine mammal monitoring plan manual will be assembled for the monitoring team prior to the start of in-water work. The manual will contain all relevant permit requirements and will describe the procedures the Seattle Department of Transportation and its contractors will implement to comply with the conditions of applicable permits.

1.2.1 Marine Mammal Sighting Form

The sighting form will capture all necessary details important to marine mammal identification and protection during pile-related activities. See Attachment A for the sample sighting form.

The monitoring form will be used to record the following information:

- Background information
  - Date, observer name, and location.
  - Environmental conditions (weather, wind, waves), plus notes on conditions that could confound marine mammal detections and the time and location that they occurred.
- For marine mammal sightings
  - Species observed, number, pod composition, distance to pile-related activities, and behavior (e.g., group cohesiveness, direction of travel) of marine mammals throughout

duration of sighting.

- Time of first and last sighting.
- Discrete behavioral reactions to construction, if apparent.
- Pile-related activities taking place concurrently with each sighting.
- Monitor response including whether a stop-work order was issued, why, and for how long, or if a take was recorded.
- The number of take(s) (by species), their locations, and behavior.

1.2.2 Acoustic Monitoring

Acoustic monitoring will be conducted during in-water pile installation and removal for a minimum of two days for each type of pile-related activity (vibratory removal of timber piles, vibratory installation of steel piles, and impact installation of steel piles). It is expected that no other pile-related activities will be occurring during monitoring of timber pile removal and vibratory installation of steel piles. It is possible that impact installation will not occur as an isolated activity; vibratory installation may be occurring concurrently.

Collection of the acoustic data will be accomplished using a minimum of two hydrophones. At least one stationary land-based microphone would also be deployed to record airborne sound levels. For underwater acoustic monitoring, the hydrophones will be placed such that there is a direct line of acoustic transmission through the water column between the impact or vibratory hammer and the hydrophones, without any interposing structures (including other piles) that could impede sound transfer, when possible. All acoustic recordings will be conducted approximately one meter below the water surface and one meter above the sea floor, or as applicable to optimize sound recordings in the nearshore environment.

Background noise recordings (in the absence of pile installation or removal) will also be made during the study to provide a baseline background noise profile. The results and conclusions of the study will be summarized and presented to NOAA/NMFS with recommendations on any modifications to this proposed plan or Exclusion Zones.

All sensors, signal conditioning equipment, and sampling equipment will be calibrated at the start of the monitoring period to National Institute of Standards and Technology standards and will be re-checked at the start of each day.

A stationary two-channel hydrophone recording system will be deployed to record continuous sound associated with pile driving and removal activities during the monitoring period. Key methodological details are as follows:

- Prior to monitoring, water depth measurements will be made to ensure that hydrophones will not drag on the bottom during tidal changes. The hydrophones will be placed approximately one meter below the surface and one meter above the seafloor. The depth with respect to the bottom may vary somewhat due to tidal changes and current effects.
- The hydrophone systems will be deployed to maintain a constant distance of approximately 10 meters from the pile-related noise source.

- The hydrophones, signal conditioning, and recording equipment will be configured to acquire maximum source levels without clipping recorded data.

To empirically verify the modeled behavioral disturbance zones, underwater and airborne acoustic monitoring would occur for two days during each type of pile installation or removal activity. In the event that underwater sound monitoring shows that noise generation from pile installation or removal consistently exceeds the anticipated noise levels, as documented in the Incidental Harassment Authorization application, NOAA/NMFS will be consulted.

Post-analysis of underwater sound level signals would include the following:

- Impact Pile Driving
  - Determination of the maximum absolute value of the instantaneous pressure within each strike.
  - Root mean square (RMS) value for the period of which 90 percent of the energy is represented (RMS 90, 5 percent to 95 percent) for each absolute peak pile strike.
  - Mean and standard deviation/error of the RMS 90 percent for all pile strikes of each pile.
  - Rise time.
  - Number of strikes per pile and per day.
  - Number of strikes exceeding 206-decibel (dB) peak.
  - Sound exposure level (SEL) of the single pile strike with the absolute peak sound pressure, mean SEL.
  - Cumulative SEL (cumulative SEL = single strike SEL + 10*LOG (number of pile strikes)).
  - Frequency spectrum, between 20 hertz (Hz) and 20 kilohertz (kHz), for up to eight successive strikes with similar sound level.
- Vibratory Pile Driving and Removal
  - RMS values (average, standard deviation/error, minimum, and maximum) for each recorded pile. The 10-second, RMS-averaged values will be used for determining the source value and extent of the 120 dB underwater isopleth.
  - Frequency spectra will be provided for each functional hearing group as outlined in NOAA's 2016 guidance (NOAA 2016).
  - All underwater source levels will be standardized to a reference distance of 10 meters (33 feet).

Post-analysis of airborne noise will be presented in an unweighted format, and will include the following:

- The unweighted RMS values (average, minimum, and maximum) for each recorded pile. The average values will be used for determining the extent of the airborne isopleths relative to species specific criteria.
- Frequency spectra will be provided from 10 Hz to 20 kHz for representative pile-related activity.
- All airborne source levels will be standardized to a reference distance of approximately 15 meters (50 feet).

Acoustic monitoring will be performed using a standardized method that will facilitate comparisons with other studies. In the event that pile-related noise trends toward consistently surpassing calculated levels, NOAA/NMFS will be contacted immediately to discuss the situation. Table 4 provides the anticipated noise levels by pile type and method.

TABLE 4. METHOD AND SOUND LEVEL SUMMARY

Construction Phase	Type	Installation/Removal Method	Source Sound Levels
Installation			
Pier 62	Steel pile 30-inch	Vibratory	177[2] dB RMS[1] / 180[3] dB RMS[1]
	Steel pile 30-inch	Impact	189 dB RMS[1]
Removal			
Pier 62	Timber pile 14-inch	Vibratory	152[2] dB RMS[1] / 155[3] dB RMS[1]

Notes:

1. WSDOT 2016
2. Single source pile driving sound level
3. Additive source sound level for two piles driven simultaneously dB – decibels

RMS – root mean square

1.3 REPORTING

In addition to capturing marine mammal monitoring data on field datasheets, a daily monitoring log and annual marine mammal monitoring and acoustic monitoring reports will be prepared.

1.3.1 Daily Monitoring Log

A running daily monitoring log will be maintained and updated at the end of each survey day, summarizing important observations and applicable aspects of construction. The daily monitoring log will summarize important details noted by the monitors in a format that readily conveys these details to interested and appropriate parties. Details of daily monitoring are provided in Section 1.3.1.

1.3.2 Annual Monitoring Reports

Each year, an annual monitoring report would be drafted and submitted to NOAA Office of Protected Resources, and NMFS Northwest Regional Office, at the end of each construction season. Each annual report would summarize information presented in the daily monitoring logs in a manner to effectively convey important marine mammal observations made during that year. The annual monitoring report would include the following:

- Data and time collected for each distinct marine mammal species observed in the project area.
- Weather conditions.

- Approximate distance between the marine mammal and the noise source.
- Activity at the construction site when a marine mammal was sited.
- A summary of take issued per species that year and to date.
- A summary of any stop-work orders given that year including number, species involved, and circumstances.
- Descriptions of marine mammal species observed, overall numbers of individuals observed, frequency of observation, behavior and any behavioral changes, and context of the changes relative to construction activities.
- Other important details that would provide context to the marine mammal observations made that year.

1.3.3 Acoustic Monitoring Report

Each year, a report providing the results of all acoustic monitoring would also be drafted and submitted to NOAA/NMFS. This reports would include the following:

- Size and type of piles monitored.
- A detailed description of any sound attenuation device used, including design specifications.
- The impact hammer energy rating used to drive the piles, description of the vibratory hammer, and make and model of the hammer(s).
- A description of the sound monitoring equipment.
- The distance between hydrophones and depth of water and the hydrophone locations.
- The depth of the hydrophones.
- The distance from the pile to the water's edge.
- The depth of water in which the pile was driven.
- The depth into the substrate that the pile was driven.
- The physical characteristics of the bottom substrate into which the pile was driven.
- The total number of strikes to drive each pile.
- The results of the hydroacoustic monitoring, including the frequency spectrum, ranges and means for the peak and RMS sound pressure levels, and an estimation of the distance at which RMS values reach the relevant marine mammal thresholds and background sound levels. Vibratory driving results would include the maximum and overall average RMS calculated from 10-second RMS values during the drive of the pile.
- A description of any observable marine mammal behavior in the immediate area and, if possible, correlation to underwater sound levels occurring at that time.

REFERENCES

Anchor QEA, 2014. *Elliott Bay Seawall Project Marine Mammal Monitoring Season 1 Annual Report*. Elliott Bay Seawall Project.

Anchor QEA, 2015. *Elliott Bay Seawall Project Marine Mammal Monitoring Season 2 Annual Report*. Elliott Bay Seawall Project.

Anchor QEA, 2016. *Elliott Bay Seawall Project Marine Mammal Monitoring Season 3 Annual Report*. Elliott Bay Seawall Project.

WSDOT (Washington State Department of Transportation), 2011. *Seattle Ferry Terminal Background Sound Measurement Results, April 2011*. Technical Memorandum, May 18, 2011.

WSDOT, 2016. *Request for an Incidental Harassment Authorization under the Marine Mammal Protection Act, Seattle Multimodal Project at Colman Dock*. Washington State Department of Transportation Ferries Division, July 2016.

NOAA (National Oceanic and Atmospheric Administration), 2016. *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts*. U.S. Dept. of Commerce, NOAA. NOAA Technical Memorandum NMFS-OPR-55, 178 p.

ATTACHMENT A
MARINE MAMMAL MONITORING FORMS

Pier 62 MarineMammal Monitoring Form

Monitoring Location: Const Site Alki Magnolia	Observer:	Date:
Weather Conditions: Sunny Overcast Rain Whitecaps	Average temp:	Other conditions:
Environmental Conditions Limiting MMM: None	Yes - describe:	
MMM Start Time:	MMM End Time:	
Pile Activity (Begin, End, Breaks):		
Monitoring Type: Vibe Impact	Communication during Monitoring:	

Species	Species #	Time Begin	Time End	Duration	PD Distance (feet)	Take #	Behavior	Reactions to Pile Activity
				______ Hours ______ Minutes			Swimming Foraging Resting[1] Intermittent Other[2]	No pile activity None observed Yes[2]
				______ Hours ______ Minutes			Swimming Foraging Resting[1] Intermittent Other[2]	No pile activity None observed Yes[2]
				______ Hours ______ Minutes			Swimming Foraging Resting[1] Intermittent Other[2]	No pile activity None observed Yes[2]
				______ Hours ______ Minutes			Swimming Foraging Resting[1] Intermittent Other[2]	No pile activity None observed Yes[2]
				______ Hours ______ Minutes			Swimming Foraging Resting[1] Intermittent Other[2]	No pile activity None observed Yes[2]
				______ Hours ______ Minutes			Swimming Foraging Resting[1] Intermittent Other[2]	No pile activity None observed Yes[2]
				______ Hours ______ Minutes			Swimming Foraging Resting[1] Intermittent Other[2]	No pile activity None observed Yes[2]
				______ Hours ______ Minutes			Swimming Foraging Resting[1] Intermittent Other[2]	No pile activity None observed Yes[2]
				______ Hours ______ Minutes			Swimming Foraging Resting[1] Intermittent Other[2]	No pile activity None observed Yes[2]

Notes:

1. Resting on mooring buoy (hauled out), debris, or shoreline.
2. Describe behavior or reaction to pile activity here.

Total Daily Takes: CSL Takes = HS Takes = Other Takes =

Pier 62 Construction Site Lead Form

Lead Monitor:

Date	Vibe Ramp-up Time	Impact Ramp-up Time	Unable to Confirm Ramp-up[1]	Start and Stop Times,[2] Comments
Notes:				

1. If unable to confirm proper ramp up procedures were followed, notify Jennifer Horwitz or the construction manager.
2. For breaks longer than one hour, ramp up procedures must be repeated. Please start a new data line.