UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
1201 NE Lloyd Boulevard, Suite 1100
Portland, OR 97232

Refer to NMFS Consultation No.:
WCRO-2019-00016

June 11, 2019

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

Re: Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Pitt Floating Pier Installation Project in Lake Union, Washington (Corps No. NWS-2018-1180)

Dear Ms. Walker:

Thank you for your letter on January 28, 2019, requesting initiation of consultation with the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) pursuant to section 7 of the Endangered Species Act of 1973 (ESA) (16 USC 1531 et seq.) for the proposed Pitt Floating Pier Installation Project in Lake Union, Washington. 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 (MSA) (16 USC 1855(b)) for this action.

The enclosed document contains the biological opinion (Opinion) prepared by NMFS pursuant to section 7(a)(2) of the ESA on the effects of the proposed action. In this Opinion, NMFS concludes that the proposed action is not likely to jeopardize the continued existence of Puget Sound (PS) Chinook salmon and PS steelhead. NMFS also concludes that the proposed action is not likely to result in the destruction or adverse modification of designated critical habitat for PS Chinook salmon.

As required by section 7 of the ESA, we are providing an incidental take statement with the opinion. The incidental take statement describes reasonable and prudent measures we consider necessary or appropriate to minimize incidental take associated with this action. The take statement sets forth nondiscretionary terms and conditions, including reporting requirements that the United States Army Corps of Engineers (Corps) and any person who performs the action must comply with to carry out the reasonable and prudent measures. Incidental take from actions that meet these terms and conditions will be exempt from the ESA take prohibition.

NMFS also reviewed the likely effects of the proposed action on EFH, pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (16 USC 1855(b)), and concluded that the action would adversely affect the EFH of Pacific Coast salmon. Therefore, we have included the results of that review in Section 3 of this document.

Please contact Melaina Wright, consulting biologist at the Oregon Washington Coastal Office (OWCO) at melaina.wright@noaa.gov or 206-526-6155 if you have any questions concerning this consultation, or if you require additional information.

Sincerely,

Kim W. Kratz, Ph.D.
Assistant Regional Administrator
Oregon Washington Coastal Office

cc: Colleen Anderson, Corps
Juliana Houghton, Corps

Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the

Pitt Floating Pier Installation Project
Lake Union, Washington
(Corps No. NWS-2018-1180)

NMFS Consultation Number: WCRO-2019-00016

Action Agency: United States Army Corps of Engineers

Affected Species and NMFS' Determinations:

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species?	Is Action Likely To Jeopardize the Species?	Is Action Likely to Adversely Affect Critical Habitat?	Is Action Likely To Destroy or Adversely Modify Critical Habitat?
Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*)	Threatened	Yes	No	Yes	No
Puget Sound steelhead (*O. mykiss*)	Threatened	Yes	No	NA	NA

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

Consultation Conducted By: National Marine Fisheries Service
West Coast Region

Issued By:

Kim W. Kratz, Ph.D.
Assistant Regional Administrator
Oregon Washington Coastal Office

Date: June 11, 2019

TABLE OF CONTENTS

FIGURES

LIST OF ACRONYMS

ºC – Degrees Celsius
ºF – Degrees Fahrenheit
ACZA – Ammoniacal Copper Zinc Arsenate
BE- Biological Evaluation
CFR – Code of Federal Regulations
Corps – United States Army Corps of Engineers
dB – Decibels
DNR – Washington Department of Natural Resources
DO – Dissolved Oxygen
DPS – Distinct Population Segment
DQA – Data Quality Act
Ecology – Washington State Department of Ecology
EF – Essential Features
EFH – Essential Fish Habitat
ESA – Endangered Species Act
ESU – Evolutionarily Significant Unit
FR – Federal Register
HAPC – Habitat Area of Particular Concern
IPCC – Intergovernmental Panel on Climate Change
ISAB – Independent Scientific Advisory Board
ITS – Incidental Take Statement
LAA-Likely to adversely affect
MFS – Memorandum for the Services
MPG – Major Population Group
MSA – Magnuson-Stevens Fishery Conservation and Management Act
NMFS – National Marine Fisheries Service
NOAA – National Oceanic and Atmospheric Administration
NWFSC – Northwest Fisheries Science Center
Opinion – Biological Opinion
OWCO – Oregon Washington Coastal Office
PAH – Polycyclic Aromatic Hydrocarbon
PBF – Physical and Biological Feature
PFMC – Pacific Fishery Management Council
PCE – Primary Constituent Element
PS – Puget Sound
RMS – Root Mean Square Sound Pressure Level
RPA – Reasonable and Prudent Alternative
RPM – Reasonable and Prudent Measure
SAV – Submerged Aquatic Vegetation
SEL – Sound Exposure Level
SEL_{cum} – Cumulative Sound Exposure Level
SSDC – Shared Strategy Development Committee
TRT – Technical Recovery Team
TSS – Total Suspended Solids

µg/L – Micrograms Per Liter
USC – United States Code
VSP – Viable Salmon Population
WCRO – West Coast Regional Office
WDFW – Washington State Department of Fish and Wildlife

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) 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 U.S.C. 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 Washington Coastal Office.

1.2. Consultation History

On January 28, 2018, NMFS received a request for formal ESA section 7 consultation from the United States Army Corps of Engineers (Corps). The initiation package included an ESA section 7 consultation initiation letter; a Memorandum for the Services (MFS); a biological evaluation (BE); and a set of project drawings. The Corps determined the action may affect, likely to adversely affect (LAA) Puget Sound (PS) Chinook salmon and their critical habitat, and PS steelhead. The Corps also determined that the project is likely to adversely affect Pacific salmon EFH. Consultation was initiated on that date.

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). Federal action means any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken by a Federal Agency (50 CFR 600.910).“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).

The Corps is proposing to authorize the Pitt Floating Pier Installation Project in Lake Union located at 1327 North Northlake Way, Seattle, Washington (47.64686, -122.34186; Figure 1, Figure 2, and Figure 3). The primary use of the pier is for moorage of small recreational vessels. The applicant is proposing to install two floating finger piers (389 square feet total) at the end of an existing pier over water greater than 30 feet deep (Figure 4 and Figure 5). The proposed action would increase vessel moorage at the pier. Therefore, vessel activity associated with the new floating piers would be interrelated and interdependent with the proposed action.

The applicant will construct the new, ThruFlow grated floating piers off site and barge them into place. They will ensure the barge does not ground out or anchor in submerged aquatic vegetation (SAV). They will secure each floating pier to the existing pier with pile hoops. They will install two 24-inch diameter steel piles with a vibratory hammer and barge-mounted crane. They will complete vibratory pile driving within 60 minutes on one day. The applicant will not proof piles with an impact hammer. They will secure the waterward end of each floating pier to one of the steel piles. They will install grated gangway ramps for each floating pier.

The applicant will also replace four existing solid-decked pier sections (363 square feet total) with fiberglass grated decking. The existing decking is not creosote- or ACZA-treated. They will replace a 715.5 square-foot solid wood canopy over one of the existing slips with clear, light-permeable roofing. During construction, they will surround the area with a floating boom, and retrieve all floating debris before they remove the boom. They will barge all removed decking off site for disposal. They will keep spill containment and removal materials on site. To minimize impacts to ESA-listed species, the applicant will only conduct work between November 1 and April 15.

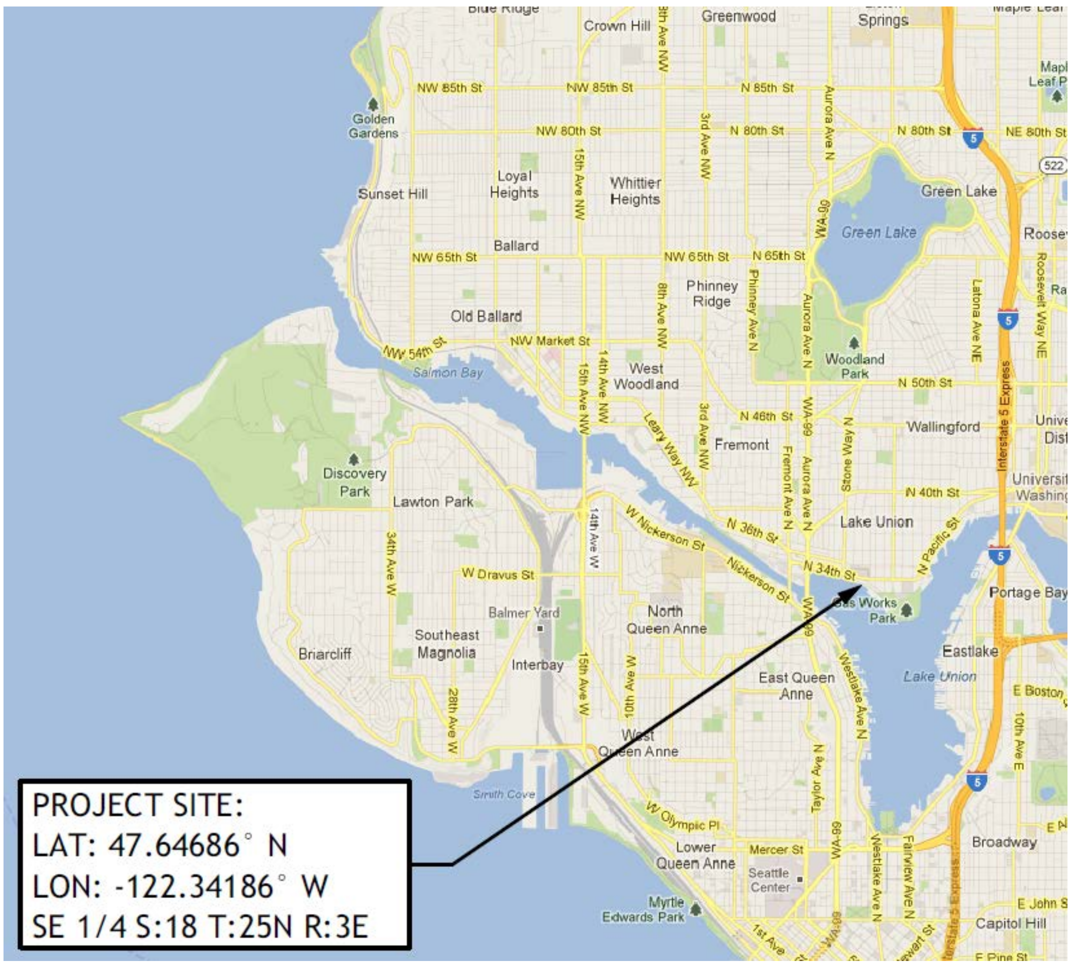

Figure 1. Project site location in Lake Union, Washington.

Figure 2. Aerial view of project site and vicinity.

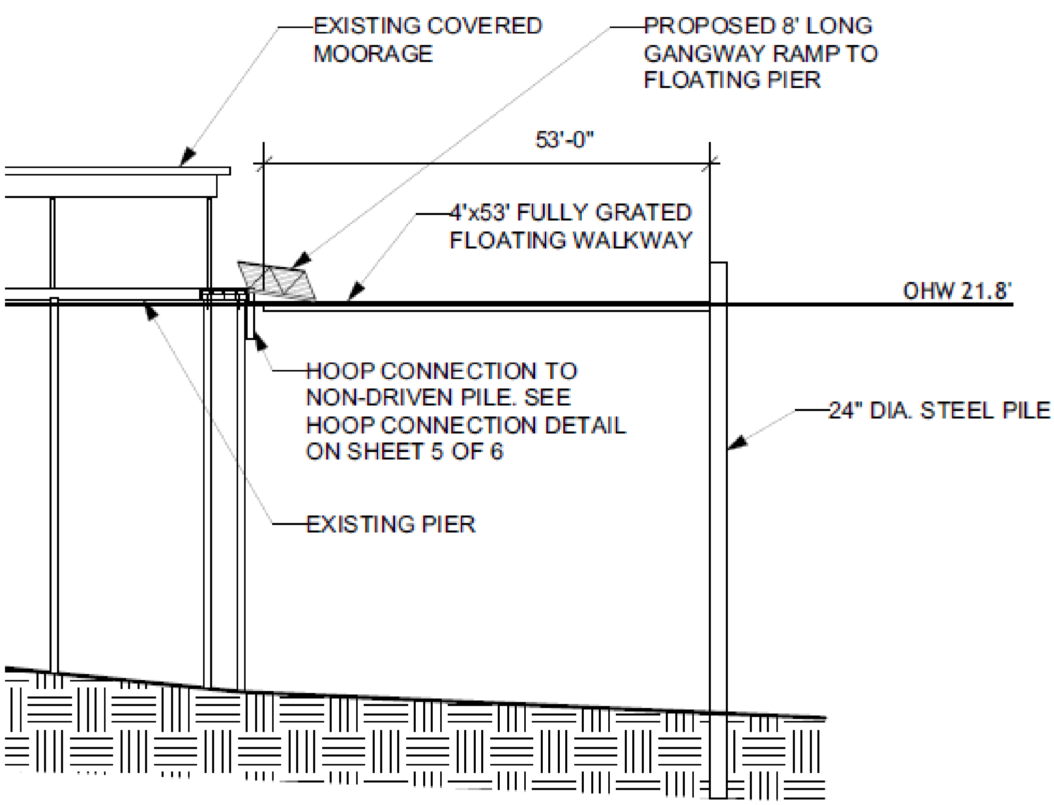

Figure 3. Lateral view of the location of one proposed floating pier, piles, grated walkway, and moorage cover to be removed.

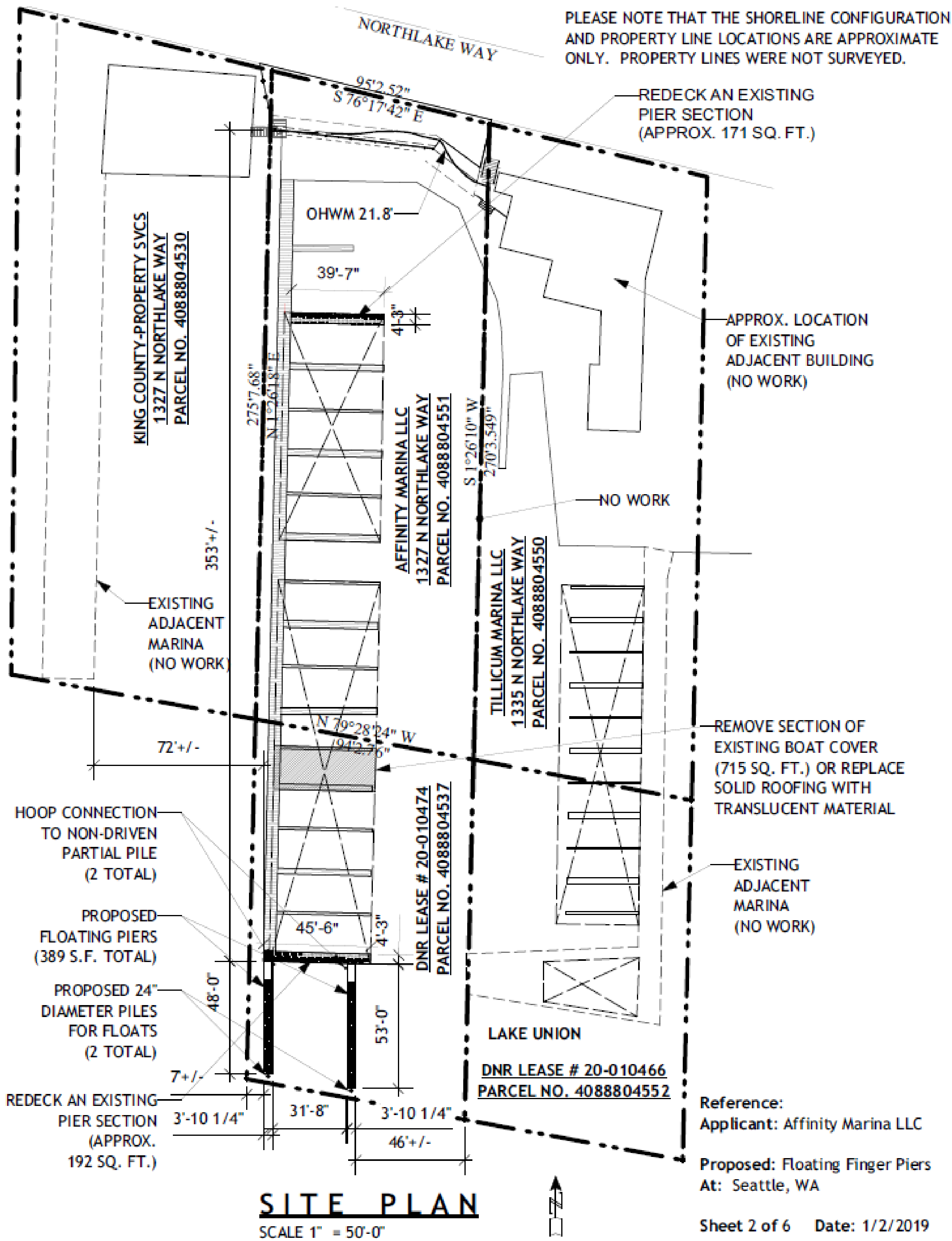

Figure 4. Aerial view of location of proposed floating piers, piles, sections of existing pier to be replaced with grated decking, and moorage cover to be removed.

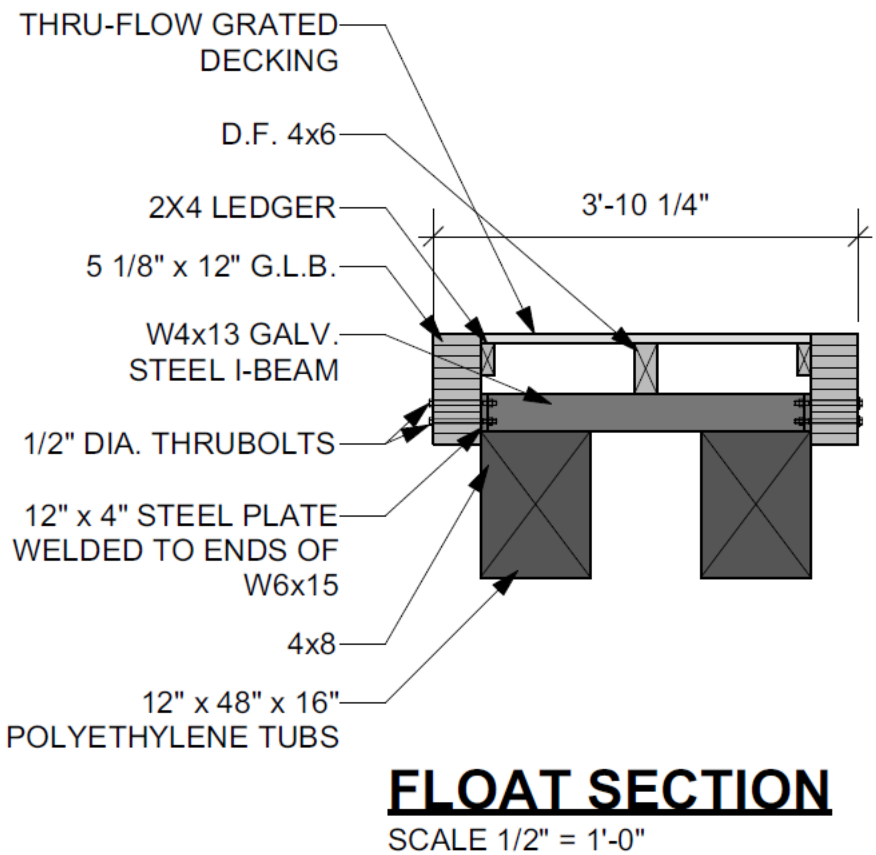

Figure 5. Cross section of one of the proposed floating finger piers.

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 ensure 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 NMFS and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provides an opinion stating how the agency's actions would affect listed species and their critical habitats. If incidental take is reasonably certain to occur, section 7(b)(4) requires NMFS 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.

2.1. Analytical Approach

This biological opinion includes both a jeopardy analysis and/or 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(s) of critical habitat for (species) use(s) 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 biological 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 reasonable and prudent alternative (RPA) to the proposed action.

2.2. Rangewide Status of the Species and Critical Habitat

This opinion examines the status of each species that would 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.

One factor affecting the status of ESA-listed species considered in this opinion, and aquatic habitat at large, is climate change. Climate change is likely to play an increasingly important role in determining the abundance and distribution of ESA-listed species, and the conservation value of designated critical habitats, in the Pacific Northwest. These changes will not be spatially homogeneous across the Pacific Northwest. The largest hydrologic responses are expected to occur in basins with significant snow accumulation, where warming decreases snow pack, increases winter flows, and advances the timing of spring melt (Mote et al. 2016; Mote et al. 2014). Rain-dominated watersheds and those with significant contributions from groundwater may be less sensitive to predicted changes in climate (Mote et al. 2014; Tague et al. 2013).

During the last century, average regional air temperatures in the Pacific Northwest increased by 1-1.4°F as an annual average, and up to 2°F in some seasons based on average linear increase per decade (Abatzoglou et al. 2014; Kunkel et al. 2013). Warming is likely to continue during the next century as average temperatures are projected to increase another 3 to 10°F, with the largest increases predicted to occur in the summer (Mote et al. 2014). Decreases in summer precipitation of as much as 30 percent by the end of the century are consistently predicted across climate models (Mote et al. 2014). Precipitation is more likely to occur during October through March, less during summer months, and more winter precipitation will be rain than snow (ISAB 2007; Mote et al. 2013; Mote et al. 2014). Earlier snowmelt will cause lower stream flows in late spring, summer, and fall, and water temperatures will be warmer (ISAB 2007; Mote et al. 2014). Models consistently predict increases in the frequency of severe winter precipitation events (i.e., 20-year and 50-year events), in the western United States (Dominguez et al. 2012). The largest increases in winter flood frequency and magnitude are predicted in mixed rain-snow watersheds (Mote et al. 2014).

Overall, about one-third of the current cold-water salmonid habitat in the Pacific Northwest is likely to exceed key water temperature thresholds by the end of this century (Mantua et al. 2009). Higher temperatures will reduce the quality of available salmonid habitat for most freshwater life stages (ISAB 2007). Reduced flows will make it more difficult for migrating fish to pass physical and thermal obstructions, limiting their access to available habitat (Isaak et al. 2012; Mantua et al. 2010). Temperature increases shift timing of key life cycle events for salmonids and species forming the base of their aquatic foodwebs (Crozier et al. 2011; Tillmann and Siemann 2011; Winder and Schindler 2004). Higher stream temperatures will also cause decreases in dissolved oxygen and may also cause earlier onset of stratification and reduced mixing between layers in lakes and reservoirs, which can also result in reduced oxygen (Meyer et al. 1999; Raymondi et al. 2013; Winder and Schindler 2004). Higher temperatures are likely to cause several species to become more susceptible to parasites, disease, and higher predation rates (Crozier et al. 2008; Raymondi et al. 2013; Wainwright and Weitkamp 2013).

As more basins become rain-dominated and prone to more severe winter storms, higher winter stream flows may increase the risk that winter or spring floods in sensitive watersheds will damage spawning redds and wash away incubating eggs (Goode et al. 2013). Earlier peak stream flows will also alter migration timing for salmon smolts, and may flush some young salmon and steelhead from rivers to estuaries before they are physically mature, increasing stress and reducing smolt survival (Lawson et al. 2004; McMahon and Hartman 1989).

In addition to changes in freshwater conditions, predicted changes for coastal waters in the Pacific Northwest as a result of climate change include increasing surface water temperature, increasing but highly variable acidity, and increasing storm frequency and magnitude (Mote et al. 2014). Elevated ocean temperatures already documented for the Pacific Northwest are highly likely to continue during the next century, with sea surface temperature projected to increase by 1.0 to 3.7^{o}C by the end of the century (IPCC 2014). Habitat loss, shifts in species' ranges and abundances, and altered marine food webs could have substantial consequences to anadromous, coastal, and marine species in the Pacific Northwest (Reeder et al. 2013; Tillmann and Siemann 2011).

Moreover, as atmospheric carbon emissions increase, increasing levels of carbon are absorbed by the oceans, changing the pH of the water. Acidification also impacts sensitive estuary habitats, where organic matter and nutrient inputs further reduce pH and produce conditions more corrosive than those in offshore waters (Feely et al. 2012; Sunda and Cai 2012).

Global sea levels are expected to continue rising throughout this century, reaching likely predicted increases of 10 to 32 inches by 2081 to 2100 (IPCC 2014). These changes will likely result in increased erosion and more frequent and severe coastal flooding, and shifts in the composition of nearshore habitats (Reeder et al. 2013; Tillmann and Siemann 2011). Estuarine-dependent salmonids such as chum and Chinook salmon are predicted to be impacted by significant reductions in rearing habitat in some Pacific Northwest coastal areas (Glick et al. 2007).

Historically, warm periods in the coastal Pacific Ocean have coincided with relatively low abundances of salmon and steelhead, while cooler ocean periods have coincided with relatively high abundances, and therefore these species are predicted to fare poorly in warming ocean conditions (Scheuerell and Williams 2005; Zabel et al. 2006). This is supported by the recent observation that anomalously warm sea surface temperatures off the coast of Washington from 2013 to 2016 resulted in poor coho and Chinook salmon body condition for juveniles caught in those waters (NWFSC 2015). Changes to estuarine and coastal conditions, as well as the timing of seasonal shifts in these habitats, have the potential to impact a wide range of listed aquatic species (Reeder et al. 2013; Tillmann and Siemann 2011).

The adaptive ability of these threatened and endangered species is depressed due to reductions in population size, habitat quantity and diversity, and loss of behavioral and genetic variation. Without these natural sources of resilience, systematic changes in local and regional climatic conditions due to anthropogenic global climate change will likely reduce long-term viability and sustainability of populations in many of these evolutionarily significant units (ESUs) (NWFSC 2015). New stressors generated by climate change, or existing stressors with effects that have been amplified by climate change, may also have synergistic impacts on species and ecosystems (Doney et al. 2012). These conditions will possibly intensify the climate change stressors inhibiting recovery of ESA-listed species in the future.

2.2.1 Status of the Species

This section provides a summary of listing and recovery plan information, status, and limiting factors for the species addressed in this opinion. More information can be found in recovery plans and status reviews for these species. These documents are available on the NMFS West Coast Region website (http://www.westcoast.fisheries.noaa.gov/).

2.3. Puget Sound Chinook Salmon

We listed the PS Chinook salmon ESU as threatened on June 28, 2005 (70 FR 37160). Recovery plans for PS Chinook salmon include the Shared Strategy for Puget Sound 2007 Plan and the NMFS 2006 Plan (NMFS 2006; SSDC 2007). The most recent status review was in 2015 (NWFSC 2015). This ESU comprises 22 populations distributed over five geographic areas. Most populations within the ESU have declined in abundance over the past 7 to 10 years, with widespread negative trends in natural-origin spawner abundance and hatchery-origin spawners present in high fractions in most populations outside of the Skagit watershed. Escapement levels for all populations remain well below the Technical Recovery Team (TRT) planning ranges for recovery, and most populations are consistently below the spawner-recruit levels identified by the TRT as consistent with recovery.

Limiting factors for PS Chinook salmon include:
1. Degraded floodplain and in river channel structure.
2. Degraded estuarine conditions and loss of estuarine habitat
3. Degraded riparian areas and loss of in river large woody debris
4. Excessive fine-grained sediment in spawning gravel
5. Degraded water quality and temperature
6. Degraded nearshore conditions
7. Impaired passage for migrating fish
8. Severely altered flow regime

2.4. Puget Sound Steelhead

We listed the PS steelhead distinct population segment (DPS) as threatened on May 11, 2007 (72 FR 26722). There are currently no recovery plans for this DPS. The most recent status review was in 2015 (NWFSC 2015). This DPS comprises 32 populations. The DPS is currently at very low viability, with most of the 32 populations and all three population groups at low viability. Long-term abundance trends have been predominantly negative or flat across the DPS. Information considered during the most recent status review indicates that the biological risks faced by the PS Steelhead DPS have not substantively changed since the listing in 2007, or since the 2011 status review. Furthermore, the PS Steelhead TRT recently concluded that the DPS was at very low viability, as were all three of its constituent major population groups (MPGs), and many of its 32 populations. In the near term, the outlook for environmental conditions affecting PS steelhead is not optimistic. While harvest and hatchery production of steelhead in PS are currently at low levels and are not likely to increase substantially in the foreseeable future, some recent environmental trends not favorable to PS steelhead survival and production are expected to continue.

Limiting factors for PS steelhead include:

1. Continued destruction and modification of habitat
2. Widespread declines in adult abundance despite significant reductions in harvest
3. Threats to diversity posed by use of two hatchery steelhead stocks
4. Declining diversity in the DPS, including the uncertain but weak status of summer-run fish
5. A reduction in spatial structure
6. Reduced habitat quality
7. Urbanization
8. Dikes, hardening of banks with riprap, and channelization

2.4.1. Status of the Critical Habitat

This section describes the status of designated critical habitat affected by the proposed action by examining the condition and trends of the essential physical and biological features of that habitat throughout the designated areas. These features are essential to the conservation of the ESA-listed species because they support one or more of the species' life stages (e.g., sites with conditions that support spawning, rearing, migration and foraging).

We designated critical habitat for PS Chinook salmon on September 2, 2005 (70 FR 52630). Critical habitat for PS Chinook salmon includes 1,683 miles of streams, 41 square miles of lakes, and 2,182 miles of nearshore marine habitat in PS. The PS Chinook salmon ESU has 61 freshwater and 19 marine areas within its range. Of the freshwater watersheds, 41 are rated high conservation value, 12 low conservation value, and eight received a medium rating. Of the marine areas, all 19 are ranked with high conservation value. Habitat threats include urbanization, dredging, armoring of shorelines, and marina and port development. These activities have diminished the availability and quality of nearshore habitats and reduced water quality across the region.

2.5. 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 for this project includes the footprint of the project and adjacent aquatic areas within 108 meters due to the spatial extent of underwater sound from vibratory pile driving (Section 2.5).

2.6. 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 "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).

As discussed in Section 1.3, the vessels most likely to moor at the pier are small recreational vehicles (i.e., pleasure craft). In-water noise in the action area is primarily characterized by vessel traffic from tug boats, fishing vessels, passenger vessels, and pleasure craft traveling through Lake Union (MarineTraffic 2019).

The shoreline in the action area is heavily urbanized, armored, and lined with piers. Substrate at the project site consists of mud overlying sand with little to no SAV. Past and ongoing anthropogenic impacts, including climate change, described in Section 2.2 have impacted ESA-listed species and critical habitat present in the action area. Industrial activities at the nearby Gas Works Park in the early 1900s and 1950s contaminated sediments with polycyclic aromatic hydrocarbons (PAHs) (Ecology 2018a). As part of cleanup efforts associated with Gas Works Park in 2000-2001, the lake bottom (including the action area) was overlaid with a clean sand sediment cap. The action area is currently listed on the Washington State 303(d) list of impaired waterways for water quality (Ecology 2018b). Sediments one hundred feet east of the marina are currently on the 303(d) list.

In the Cedar River, the number of natural-origin spawning adult PS Chinook salmon has fluctuated between 306 and 1,893 individuals between 2004 and 2017 (WDFW 2019a). In the Sammamish, the number of natural spawners has fluctuated between 33 and 638 between 2004 and 2017 (WDFW 2019a). Adult Chinook salmon migrate through the Chittenden Locks from mid-June through September, with most adults moving through the Lake Washington Ship Canal and Lake Union in less than 1 day (City of Seattle 2008). Juvenile PS Chinook salmon generally migrate out of Lake Washington and Lake Sammamish from late May to early July, and spend approximately 1 to 4 weeks moving through the Ship Canal and Lake Union. However, some juvenile Chinook may be present in Lake Union through October (City of Seattle 2019).

There are very few Lake Washington Basin steelhead. In the Cedar River, 10 or fewer adult natural-spawners have returned a year since 2007 (WDFW 2019b). In tributaries to North Lake Washington and Lake Sammamish, fewer than 10 adult natural-spawners returned between 1994 and 1999 (WDFW 2019b). North Lake Washington and Sammamish tributaries have not been monitored since 2000. Due to the small numbers of steelhead seen at the Chittenden Locks and estimated in the Cedar River, it is unlikely there are currently many steelhead in these tributaries.

Wild steelhead are closely related to resident *O. mykiss*. Resident *O. mykiss* are abundant below Landsburg dam and are a native wild population. Marshall et al. (2004) found that resident Cedar River *O. mykiss* produce out-migrating smolts and speculated that steelhead could produce adult resident *O. mykiss*. They concluded that the conservation of resident *O. mykiss* is likely an important aspect of reducing extinction risk for steelhead.

Returning steelhead pass through Chittenden Locks and the Lake Washington Ship Canal between January and May, and may remain within Lake Washington through June (City of Seattle 2008). Juvenile steelhead enter Lake Washington in April, and typically migrate through the ship canal and past the action area to the locks between April and May.

2.7. 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.

2.7.1. Effects on Species

Underwater Noise

NMFS established the injury thresholds for impulsive sound at 206 dB peak, 187 dB cumulative sound exposure level (SEL_{cum}) for fish more than 2 grams, and 183 dB SEL_{cum} for fish less than 2 grams (Fisheries Hydroacoustic Working Group 2008). The behavioral disturbance threshold is 150 dB root mean square (RMS). Any received level below 150 dB sound exposure level (SEL) is considered “Effective Quiet” (Stadler and Woodbury 2009).

While impact pile driving produces an intense impulsive underwater noise, vibratory pile driving produces a lower level continuous noise (Duncan et al. 2010) that does not injure fish. Fish consistently avoid sounds like those of a vibratory hammer (Dolat 1997; Enger et al. 1993; Knudsen et al. 1997; Sand et al. 2000) and appear not to habituate to these sounds, even after repeated exposure (Dolat 1997; Knudsen et al. 1997). Caltrans (2015) reports an underwater sound level 170 dB RMS at 5 meters for vibratory driving 36-inch steel piles. The noise from the pile installation will attenuate to 150 dB RMS within 108 meters. We expect the noise from vibratory driving 24-inch steel piles to be less than or equal to this value.

As described in Section 2.4, it is extremely unlikely that adult and juvenile PS Chinook salmon will be present during the in-water work window of November 1 to April 15. Therefore, the effects of in-water noise from vibratory pile driving on PS Chinook salmon are extremely unlikely to occur. Any of the few adult or juvenile PS steelhead that may occur could be displaced from the area within 108 meters of pile installation for the one hour of vibratory pile driving. However, given the short duration of the installation and the availability of similar habitat adjacent to the affected area, individuals are extremely unlikely to experience any adverse effects from vibratory pile installation.

Vessel moorage at the pier will increase with implementation of the proposed action. The vast majority of that activity will likely occur during daylight hours, but some pre-dawn or post-dusk engine running and vessel movement may take place at the site. In the absence of specific use estimates, this assessment assumes that on any given day, 12 hours of continuous vessel noise is likely to occur, which likely overestimates exposure risk most of the time. Unlike construction noises, vessel noise could occur year-round. As discussed in Section 1.3, the vessels most likely to moor at the marina are small, private recreational vessels (i.e., sailing vessels, motor yacht, and yachts). These vessels produce non-impulsive sound. Source levels for this type of vessel are 159 dB ± 9 dB (Veirs et al. 2016). However, the available information describes vessels running at or close to full-speed, which is likely to overestimate exposure risk. Because SEL is often identical to RMS for non-impulsive sources, we assume that are reported sound levels by Veirs et al. (2016) are in dB RMS which would, at worst, overestimate sound levels.

Based on the best available information, fish will be unaffected by non-impulsive noise levels under 150 dB SEL (Stadler and Woodbury 2009). To conservatively estimate source levels, we also assume that the mean plus the standard deviation represents the source level for each vessel class. We conservatively assume that the area of continuous acoustic affect (above 150 dB SEL) will include all of the water within 16 meters around the pier. Vessel noise may temporarily displace fish from this area.

Vessel noise would be short in duration and episodic in nature. The affected area would be small in size. Only low numbers of juvenile PS Chinook salmon and PS steelhead may be present at the project site at any given time. Therefore, the numbers of individuals that may be exposed to structure-related noise would likely comprise extremely small subsets of the cohorts from their respective populations. Thus, the numbers of exposed fish would be too low to cause any detectable population-level effects.

Turbidity

In-water pile driving will cause short-term and localized increases in turbidity and total suspended solids (TSS). Because the applicant will install new piles using a vibratory hammer (Section 1.3), mobilized sediments during pile installation will not exceed 300 feet from the project site and will return to background levels quickly (Bloch 2010). Turbidity, pile installation, and anchor placement effects on SAV that may exist at the project site will be highly localized, and impact only a small fraction of the available substrate in the area. Therefore, listed salmonids are extremely unlikely to experience any adverse effects from elevated TSS, pile installation, and anchor placement.

Mobilization of anaerobic sediments can decrease dissolved oxygen (DO) levels (Hicks et al. 1991; Morton 1976). However, given the small amount of sediment that will be mobilized by this project and the small area affected, any impacts on DO will be too small and short-lived to affect listed salmonids.

Contaminants

Vibratory pile installation will mobilize contaminated sediments and introduce toxic materials will be introduced to the water. Contaminants in the sediment of the action area are likely to include PAHs. Most lighter-weight PAHs will dissipate via evaporation and dilution within a few hours after their release into the water (Smith 2008; Werme et al. 2010). The remaining contaminants will quickly be diluted or settle out of the water along with the sediments.

There are two pathways for PAH exposure to listed fish species in the action area, direct uptake through the gills and dietary exposure (Karrow et al. 1999; Lee and Dobbs 1972; McCain et al. 1990; Meador et al. 2006; Neff et al. 1976; Roubal et al. 1977; Varanasi et al. 1993). 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 prey, including amphipods and copepods, uptake PAHs from contaminated sediments (Landrum et al. 1984; Landrum and Scavia 1983; Neff 1982).Varanasi et al. (1993) found high levels of PAHs in the stomach contents of juvenile Chinook salmon in the Duwamish estuary.

The primary effects of PAHs on salmonids from both uptake through their gills and dietary exposure are immunosuppression and reduced growth. Karrow et al. (1999) characterized the immunotoxicity of creosote to rainbow trout (*Oncorhynchus 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. In order to isolate the effects of dietary exposure of PAHs on juvenile Chinook salmon, Meador et al. (2006) fed a mixture of PAHs intended to mimic those found by Varanasi et al. (1993) in the stomach contents of field-collected fish. These fish showed reduced growth compared to the control fish.

Listed fish that currently use the habitat near the pier are likely to be exposed to PAHs. NMFS expects that increased PAHs in the water column and sediments will be within the 300-foot area of increased suspended sediment caused by vibratory pile driving. The water and substrate within 300 feet of pile installation activities will have increased levels of PAHs for at least three years (Romberg 2005). Some of the listed fish exposed to PAHs from the proposed action will experience immunosuppression and reduced growth, which, in some cases will increase the risk of death. Because they are shoreline-oriented and spend a greater amount of time within the action area, juvenile Chinook salmon will have the highest probability of exposure to PAHs. However, NMFS cannot discount the probability of adult and juvenile steelhead and adult Chinook salmon exposure.

Within this area, contaminants may be biologically available for years, at steadily decreasing levels. While present, contaminants such as PAHs are likely to bioaccumulate in benthic invertebrates (Landrum et al. 1984; Landrum and Scavia 1983; Neff 1982), some of which will be consumed by juvenile Chinook salmon that forage in Lake Union. Fish have low PAH uptake efficiency (Niimi and Dookhran 1989; Niimi and Palazzo 1986) and metabolize PAHs rapidly (Hellou and Payne 1986; Roubal et al. 1977; Statham et al. 1978; Varanasi et al. 1989). Nevertheless, even brief exposure to PAH-contaminated habitats has been shown to reduce growth, suppress immune competence, and increased mortality in outmigrating juvenile Chinook salmon (Varanasi et al. 1993). Meador et al. (2006) also found that dietary exposure to PAHs causes reduced growth and reduced lipid stores in juvenile Chinook salmon. In contrast, it is unlikely that adult listed salmonids and rockfish that feed on forage fish would be impacted as biomagnification of PAHs does not occur in fish (Suedel et al. 1994).

The annual number of juvenile and adult PS Chinook salmon and PS steelhead that may be exposed to PAH-contaminated forage that will be attributable to this action is unquantifiable with any degree of certainty, as is the amount of contaminated prey that any individual fish may consume, or the intensity of any effects that an exposed individual may experience. However, the small affected area and the low volume of contaminated sediment that would be brought to the surface suggest that the probability of trophic connectivity to the contamination would be very low for any individual fish. Therefore, the numbers of fish that may be annually exposed to contaminated prey would be very low, and no detectable effects at the population level for PS Chinook salmon and PS steelhead are expected.

Vessels that will continue to utilize the moor at the marina may discharge petroleum-based fuels and lubricants that contain PAHs. As described earlier, the potential effects of exposure to PAHs can range from avoidance of an area to mortality, depending on the compound and its concentration (Meador et al. 2006). Any fuels and lubricants that may be used tend to evaporate quickly, with PAH dissipating within a few hours (Werme et al. 2010). Based on the available information, the concentrations and residence times of vessel-related petroleum-based substances will be too low to cause detectable effects.

Based on the best available information, as described above, adult and juvenile PS Chinook salmon and PS steelhead may be exposed to structure-related water quality impacts will experience no more than temporary low-level behavioral effects that, individually, or in combination will not affect the fitness or normal behaviors of exposed individuals.

Shade

Intense shade can limit primary production and reduce the diversity of the aquatic communities under overwater structures (Nightingale and Simenstad 2001; Simenstad et al. 1999). The new floating piers, and the vessels that will more at them, will be situated over relatively deep water (greater than 30 feet). At those depths, vessel shade will be minimally detectable near the substrate, and will cause no more than minimal effects on the productivity and diversity of the aquatic communities within its footprint. Consequently, the effects of the structure's shade on productivity and diversity will be undetectable in listed salmonids.

Numerous studies demonstrate that juvenile salmon, in both marine and freshwater habitats, are more likely to avoid the shadow of an overwater structure than to pass through the shadow (Celedonia et al. 2008a; Celedonia et al. 2008b; Kemp et al. 2005; Moore et al. 2013; Munsch et al. 2014; Nightingale and Simenstad 2001; Ono et al. 2010; Southard et al. 2006). Though grating will increase light penetration, shading will still occur. As discussed in Section 1.3, the applicant will be using ThruFlow grated decking for their north-south oriented pier. DNR (2014) found that only 25 percent to 30 percent of light can be transmitted through a ThruFlow grated deck, oriented north to south, and raised 0 to 18 inches above the water's surface. Further, very little light will penetrate through the polyethylene tubs beneath the new finger piers (Figure 5).

An implication of juvenile salmon avoiding overwater structures is that some of them will swim around the structure (Nightingale and Simenstad 2001). This behavioral modification will cause them to temporarily utilize deeper habitat, thereby exposing them to increased piscivorous predation. This has been shown in the marine environment where juvenile salmonid consumption by piscivorous predators increased fivefold when juvenile pink salmon were forced to leave the shallow nearshore (Willette 2001). Likewise, artificial illumination from the new finger piers and additional vessels may increase vulnerability to predators. Further, swimming around overwater structures lengthens the salmonid migration route, which is correlated with increased mortality (Anderson et al. 2005). In summary, the increase in migratory path length from swimming around the new finger piers as well as the increased exposure to piscivorous predators in deeper water likely will result in proportionally increased juvenile PS Chinook mortality.

The annual number of juvenile PS Chinook salmon that may be exposed to increased predation and longer migration distances attributable to this action is unquantifiable with any degree of certainty. However, the small affected area suggests that the probability of mortality would be very low for any individual fish. Therefore, the numbers of fish that may be annually exposed to increased predation and longer migration distances will be very low, and no detectable effects at the population level are expected.

Adult PS Chinook salmon and PS steelhead will likely be too large to be affected by increased predation due to their size. Juvenile PS steelhead will move quickly through Lake Union and will be relatively large and free from shoreline obligation. Therefore, like adults, they are unlikely to face increased predation due to the presence of the structure.

Propeller Wash

Propellers and propeller wash can mobilize sediments and dislodge aquatic organisms, including SAV. In shallow water areas with high levels of vessel traffic, propeller scour can dramatically reduce SAV and diminish the density and diversity of the benthic community. However, the vessels moored at the pier will be situated over relatively deep water (greater than 30 feet), and the vessels that will operate near it would likely do so at low power levels. Based on the water depths and low power levels expected near the pier, propeller wash will be very unlikely to cause detectable effects on benthic resources. Therefore, there will be no detectable effect on listed salmonids.

Killgore et al. (2011) report that fish are killed by spinning boat propellers. Propeller-related turbulence has also been documented to kill small aquatic organisms like copepods (Bickel et al. 2011). Small fish that are exposed to propeller wash may also be displaced by the fast-moving turbulent water. Propeller wash is unlikely to affect adult PS Chinook salmon and PS steelhead, because they are unlikely to approach close enough to operating boats to be exposed. In the unlikely event of adult exposure, their increased size and swimming ability suggest that they will swim away from the propeller wash with no detectable effects other than a very brief avoidance behavior.

Juvenile PS Chinook salmon and PS steelhead that migrate past the pier are likely to be relatively close to the surface where they may be exposed to spinning propellers and propeller wash, and will be too small to effectively swim against the turbulent water. Therefore, juvenile PS Chinook salmon and juvenile PS steelhead may be injured, killed, or displaced by propellers or propeller wash. Although the likelihood of this interaction is very low for any individual fish or any individual boat trip, it is likely that over the life of the pier, at least some juvenile Chinook salmon and steelhead will experience reduced fitness or mortality from exposure to spinning propellers and/or propeller wash at the site. The annual number of individuals that may be impacted by this stressor is unquantifiable with any degree of certainty. However, based on the expectation that exposed individuals would be very small subsets of the cohorts from their respective populations, the numbers of exposed fish will be too low to cause detectable population-level effects.

2.7.2. Effects on Critical Habitat

Past critical habitat designations have used the terms primary constituent elements (PCE) or essential features (EF) to identify important habitat qualities. The new critical habitat regulations (81 FR 7214) replace those terms with physical or biological features (PBF). This shift in terminology does not change the approach used in conducting our analysis, whether the original designation identified PCE, EF, or PBF.

Designated critical habitat within the action area for PS Chinook salmon consists of freshwater migration corridors and their essential and biological features. The PBFs of designated PS Chinook salmon critical habitat in the action area include 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 supporting juvenile and adult mobility and survival.

Free of Obstruction and Excessive Predation

The proposed action will cause long-term minor effects on obstruction and episodic ephemeral effects on predation. The proposed action will also increase the area of an overwater structure that may affect shoreline migration by juveniles. The proposed action will cause no change in the abundance of predators, but the increased overwater cover may cause increased predation on juveniles. The proposed action will act to maintain this PBF at a reduced functional level compared to undisturbed areas. Therefore, the action will cause a long-term minor change in the quality and function of this PBF.

Water Quantity

The proposed action will have no effect on water quantity, and will cause no change in the quality and function of this PBF.

Water Quality

The proposed action will cause episodic ephemeral effects on water quality. Construction will briefly mobilize contaminated sediments, and may also very slightly reduce DO in very limited areas. Detectable construction-related effects on water quality are expected to be limited to the area well within 300 feet around the project site, and are not expected to persist past one or two hours after work stops. Therefore, the action will cause no long-term negative change in the quality and function of this PBF.

Forage

The proposed action will cause long-term minor effects on forage. Construction will mobilize small amounts of PAH-contaminated sediments that could be taken up by benthic invertebrates that are forage resources for juvenile salmon. Sediment distribution will be limited to the area well within 300 feet around the project site, but detectable levels of contaminants may persist for years. The structure will maintain this PBF at a slightly reduced functional level compared to undisturbed areas. In summary, the action will not reduce available forage resources, but may slightly increase contamination levels in some prey organisms within about 300 feet of the site. Therefore, the action will cause a long-term minor change in the quality and function of this PBF.

Natural Cover

The proposed action will cause long-term minor effects on natural cover. Increased TSS from construction may temporarily shade small areas of SAV that will recover within months if damaged. The action will also increase overwater cover, portions of which may shade SAV. However, given that the new floating piers and associated vessels will be situated in relatively deep water, shade will be minimally detectable near the substrate. The proposed action will maintain this PBF at a slightly reduced functional level compared to undisturbed areas. Therefore, the action will cause no long-term negative change in the quality and function of this PBF.

2.8. 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.

Vessel activity in Lake Union likely to continue in the future. As discussed in Section 2.5, vessel activity may impact listed species and habitat through increased underwater noise, exposure to PAHs, and propeller wash. Additionally, some continuing non-Federal activities are reasonably certain to contribute to climate effects 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).

2.9. 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 2.6), 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 diminishes the value of designated or proposed critical habitat for the conservation of the species.

2.9.1. ESA-listed Species

The species considered in this Opinion have been listed under the ESA, based on declines from historic levels of abundance and productivity, loss of spatial structure and diversity, and an array of limiting factors as a baseline habitat condition. Each species will be affected over time by cumulative effects, some positive – as recovery plan implementation and regulatory revisions increase habitat protections and restoration, and some negative – as climate change and unregulated or difficult to regulate sources of environmental degradation persist or increase. Overall, to the degree that habitat trends are negative, as described below, effects on viability parameters of each species are also likely to be negative. In this context we consider the effects of the proposed action's effect on individuals of the listed species at the population scale. The action area provides habitat for freshwater life histories of PS Chinook salmon and PS steelhead.

PS Chinook Salmon

The action area supports PS Chinook salmon adult and juvenile migration. The long-term trend in abundance of the PS Chinook salmon ESU is slightly negative. Reduced or eliminated accessibility to historically important habitat, combined with degraded conditions in available habitat appear to be the greatest threats to the recovery of PS Chinook salmon. Degraded water quality and temperature, degraded nearshore conditions, and impaired passage for migrating fish also continue to impact this species.

The environmental baseline within the action area has been degraded from shoreline development and maritime activities, and by nearby upland urbanization. The project site is currently listed on the Washington State 303(d) list of impaired waterways for water quality (Ecology 2018b). However, the project site is located along the Lake Washington Ship Canal, which provides the only route to and from the marine waters for adults and juveniles of the Cedar River and North Lake Washington / Lake Sammamish PS Chinook salmon populations.

Project-related work will avoid the presence of out-migrating juvenile PS Chinook salmon and returning adults. For the first few years following construction, out-migrating juveniles may be exposed to ever-decreasing levels of contaminated forage, due to mobilization of small amounts of contaminated sediments during pile installation. Consumption of contaminated forage may reduce growth, increase susceptibility to infection, and increase mortality in some individuals. The shade cast by the pier may increase mortality in juvenile PS Chinook salmon through increased predation and migratory path length. Propellers and propeller wash associated with continued use of the structure may also injure, kill, or displace juvenile PS Chinook salmon. The number of PS Chinook salmon that are likely to be injured or killed by action-related stressors is unknown, but is expected to be very low, and such a small fraction of a returning cohort that it will have no detectable effect on any of the characteristics of a viable salmon population (VSP), abundance, productivity, distribution, or genetic diversity) for the affected population(s). Similarly, the annual number of juveniles that are likely to be injured or killed by exposure to action-related stressors is also unknown, but is expected to be too low to cause detectable effects on any VSP characteristics for the affected population(s).

The proposed action will increase the area of overwater cover, which will keep certain habitat conditions at slightly reduced functional levels as compared to undisturbed areas. However, the structure will not cause or worsen any habitat conditions in a manner that would act to limit the recovery of this species. Based on the best available information, the scale of the direct and indirect effects of the proposed action, when considered in combination with the degraded baseline, cumulative effects, and the impacts of climate change, will be too small to cause any population level impacts on PS Chinook salmon. Therefore, the proposed action will not appreciably reduce the likelihood of survival and recovery of this listed species.

PS Steelhead

The action area supports adult and juvenile migration. The DPS is currently at very low viability, and long-term abundance trends have been predominantly negative or flat across the DPS. Continued destruction and modification of habitat, widespread declines in adult abundance, and declining diversity appear to be the greatest threats to the recovery of PS steelhead. Reduced habitat quality and urbanization also continue to impact this species.

The environmental baseline within the action area has been degraded from shoreline development and maritime activities, and by nearby upland urbanization. The project site is currently listed on the Washington State 303(d) list of impaired waterways for water quality (Ecology 2018b). However, the project site is located along the Lake Washington Ship Canal, which provides the only route to and from the marine waters for adults and juveniles of the Cedar River and North Lake Washington / Lake Sammamish DIPs. Ten or fewer adult natural-spawner Cedar River and North Lake Washington / Lake Sammamish PS steelhead are estimated to remain.

The proposed project-related work overlaps with presence of out-migrating juvenile PS steelhead and returning adults. During construction, very low numbers of juveniles and adults may experience displacement due to noise. Propellers and propeller wash associated with continued use of the pier may also injure, kill, or displace juvenile PS steelhead. The number of PS steelhead that are likely to be injured or killed by action-related stressors is unknown, but is expected to be very low, and such a small fraction of a returning cohort that it will have no detectable effect on any of the characteristics of a VSP, abundance, productivity, distribution, or genetic diversity) for the affected population(s). Similarly, the annual number of juveniles that are likely to be injured or killed by exposure to action-related stressors is also unknown, but is expected to be too low to cause detectable effects on any VSP characteristics for the affected population(s).

Based on the best available information, the scale of the direct and indirect effects of the proposed action, when considered in combination with the degraded baseline, cumulative effects, and the impacts of climate change, will be too small to cause any population level impacts on PS steelhead. Therefore, the proposed action will not appreciably reduce the likelihood of survival and recovery of this listed species.

2.9.2. Critical Habitat

As described above at Section 2.5.2, the proposed action is likely to adversely affect designated critical habitat for PS Chinook salmon. Past and ongoing anthropogenic activities have degraded salmonid critical habitat throughout the Puget Sound basin. Hydropower and water management activities have reduced or eliminated access to significant portions of historic spawning habitat. Timber harvests, agriculture, industry, urbanization, and shoreline development have adversely altered floodplain and stream morphology in many watersheds, diminished the availability and quality of estuarine and nearshore marine habitats, and reduced water quality across the region. Future non-federal actions and climate change are likely to increase and continue acting against the quality of salmonid critical habitat. The intensity of those influences on salmonid habitats is uncertain, as is the degree to which those impacts may be tempered by adoption of more environmentally acceptable land use practices, implementation of non-federal plans that are intended to benefit salmonids, and efforts to address the effects of climate change.

PS Chinook salmon critical habitat in the action area is limited to freshwater migration corridors. PBFs that will be affected by the action are limited to freedom of obstruction and excessive predation, water quality, natural cover, and forage. As described above, the project site is located along a heavily impacted waterway, and currently functions at greatly reduced levels as compared to undisturbed freshwater migratory corridors.

The proposed action will cause minor episodic ephemeral effects on water quality and natural cover, and long term minor effects on forage. Construction will cause brief minor impacts on water quality within about 300 feet of the site. Increased TSS from construction may temporarily shade small areas of SAV that would recover within months if damaged. The proposed action will cause no measurable changes in availability of forage resources, but may slightly increase prey contamination within about 300 feet of the site for a low number of years.

The proposed action will cause long-term minor effects on obstruction and natural cover. The proposed action will increase overwater cover, which may affect shoreline migration by juveniles. The proposed action will cause no change in the abundance of predators, but the presence of the overwater structure may cause increased predation. Additionally, the new floating finger piers may shade existing SAV at the site. The proposed action will act to maintain this PBF at a reduced functional level compared to undisturbed areas. Therefore, the action will cause a long-term minor change in the quality and function of this PBF.

The proposed action will increase the area of overwater cover, which will keep certain habitat conditions at slightly reduced functional levels as compared to undisturbed areas. However, based on the best available information, the scale of the proposed action’s effects, when considered in combination with the degraded baseline, cumulative effects, and the impacts of climate change, will be too small to cause any detectable long-term negative changes in the quality or functionality of freshwater migration corridor PBFs in the action area. Therefore, this critical habitat will maintain its current level of functionality, and retain its current ability for PBF to become functionally established, to serve the intended conservation role for PS Chinook salmon.

2.10. 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 NMFS’ biological opinion that the proposed action is not likely to jeopardize the continued existence of PS Chinook salmon and PS steelhead, nor is it likely to destroy or adversely modify designated critical habitat for PS Chinook salmon.

2.11. 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). “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.

2.11.1. Amount or Extent of Take

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

Harm of PS Chinook salmon from
- contaminated forage,
- structure-related altered migratory behaviors,
- structure-related predation, and
- structure-related propeller wash.

Harm of PS steelhead from
- exposure to noise from pile driving, and
- structure-related propeller wash.

The distribution and abundance of fish that occur within an action area are affected by habitat quality, competition, predation, and the interaction of processes that influence genetic, population, and environmental characteristics. These biotic and environmental processes interact in ways that may be random or directional, and may operate across far broader temporal and spatial scales than are affected by the proposed action. Thus, the distribution and abundance of fish within the action area cannot be attributed entirely to habitat conditions, nor can NMFS precisely predict the number of fish that are reasonably certain to be injured or killed if their habitat is modified or degraded by the proposed action.

Therefore, we cannot predict with meaningful accuracy the number of juvenile and adult PS Chinook salmon and PS steelhead that are reasonably certain to be injured or killed by exposure to these stressors. Additionally, NMFS knows of no device or practicable technique that would yield reliable counts of individuals that experience these impacts. In such circumstances, NMFS uses the causal link established between the activity and the likely extent and duration of changes in habitat conditions to describe the extent of take as a numerical level of habitat disturbance. The most appropriate surrogates for take are action-related parameters that are directly related to the magnitude of the expected take.

Noise from Pile Driving

For take resulting from noise, we use the geographic extent of noise as a habitat surrogate. This surrogate is proportional to the amount of take, because we expect an increased number of individuals exposed to project-related noise with increasing geographic extent of the noise. The take represented by this surrogate is equivalent to the maximum amount of take considered in our jeopardy analysis. Therefore, if the surrogate is exceeded, reinitiation of consultation will be required. This surrogate will function as an effective reinitiation trigger, because the extent of noise can be can and will be measured and reported.

Increased Suspended Sediment and Contaminated Forage

For increased suspended sediment and PAH exposure, the best available indicator for the extent of take is the extent of visible increased turbidity. Based on past projects (Bloch 2010), the observed extent of turbidity is a reliable indicator of the extent of elevated suspended sediment, and therefore, the extent of exposure of to listed species. Because PAHs will be released during activities that increase suspended sediment, the observed extent of turbidity is a reliable indicator of the extent of PAH exposure. Therefore, if the surrogate is exceeded, reinitiation of consultation will be required. This surrogate will function as an effective reinitiation trigger, because the extent of visible turbidity can be can and will be measured and reported.

Altered Migratory Behaviors, Predation, and Propeller Wash

For take resulting from the overwater structure, we use the square footage of overwater cover as a habitat surrogate. This surrogate is proportional to the amount of take, because we expect migration delays, additional vulnerability to predators, and additional vessel activity and associated propeller wash with increasing coverage of the water's surface. The take represented by this surrogate is equivalent to the maximum amount of take considered in our jeopardy analysis. Therefore, if the surrogate is exceeded, reinitiation of consultation will be required. This surrogate will function as an effective reinitiation trigger because the area of overwater cover can and will be measured and reported.

In summary, the extent of take for this action is defined as:

PS Chinook salmon:
1. Geographic extent of visible turbidity; and
2. Area of overwater cover.

PS steelhead:
3. Geographic extent of underwater noise;
4. Geographic extent of visible turbidity; and

5. Area of overwater cover.

Exceedance of any of the exposure limits described above would constitute an exceedance of authorized take that would trigger the need to reinitiate consultation.

2.11.2. Effect of the Take

In the biological opinion, NMFS 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.

2.11.3. 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). NMFS believes that the full application of the reasonable and prudent measures described below is necessary and appropriate to minimize the likelihood of incidental take of ESA-listed species.

The Corps shall:

1. Implement monitoring and reporting to confirm that the take exemption for the proposed action is not exceeded.

2.11.4. Terms and Conditions

The terms and conditions described below are non-discretionary, and the Corps or any applicant must comply with them in order to implement the RPMs (50 CFR 402.14). The Corp 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 would likely lapse.

To implement RPM Number 1, the Corps shall require the applicant to collect and report details about the take of listed species. That plan shall:

1. Require the contractor to maintain and submit construction logs to verify that all take indicators are monitored and reported. The logs should indicate:
   - 1.1 A maximum of 60 minutes of vibratory pile installation in one day;
   - 1.2 A visible turbidity plume not to exceed 300 feet from the project site during any portion of the project;
   - 1.3 New floating finger piers no greater than 389 square feet total.

2. Submit an electronic post-construction report to NMFS within six months of project completion. Send the report to: projectreports.wcr@noaa.gov. Be sure to include the NMFS Tracking number for this project in the subject line: Attn: WCRO-2019-00016.

2.12. 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).

1. The Corps and applicant should encourage contractors to use the lowest safe maneuvering speeds and power settings when maneuvering in shallow water close to the shoreline, with the intent to minimize propeller wash.
2. The Corps should encourage the applicant to require their contractors to install full-depth silt curtains around in-water pile installation to minimize the spread of contaminated sediments.
3. The Corps should encourage the applicant to install clean capping material over substrates where contaminated sediments may settle out after pile installation.
4. The Corps should encourage the applicant to develop a plan to reduce the environmental impacts of the pier. Suggested measures include:
    - 4.1 Instruct patrons about the importance of nearshore marine habitats at the site to migrating juvenile salmon;
    - 4.2 Require patrons to operate vessels at low speeds near the pier and other shallow shoreline areas;
    - 4.3 Require patrons to maintain and operate their vessels with the intent to reduce the potential for toxic chemicals to enter or remain in the water at the site; and
    - 4.4 Establish a system to prevent and/or remove litter and wastes from the area around the pier.
5. The Corps should coordinate with NMFS, other resource agencies, and technical experts to address contaminated sediments and water quality issues in Lake Union and the ship canal.
6. The Corps should conduct or support continuing research to better understand the distribution, abundance, and habitat use of PS Chinook salmon and PS steelhead in Lake Union and the ship canal.

2.13. Re-initiation of Consultation

This concludes formal consultation for the Corps. 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.

3. MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT

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 Corps and descriptions of EFH for Pacific Coast salmon (PFMC 2014) 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 in Sections 1 and 2 of this document. The action area includes areas designated as EFH for various life-history stages of Pacific Coast salmon (PFMC 2014). The action area is not designated as a habitat area of particular concern (HAPC).

3.2. Adverse Effects on Essential Fish Habitat

The ESA portion of this document describes the adverse effects of this proposed action on ESA-listed species and critical habitat, and is relevant to the effects on EFH for Pacific coast salmon. Based on the analysis of effects presented in Section 2.5, the proposed action will cause small-scale adverse effects on this EFH through direct or indirect physical, chemical, or biological alteration of the water or substrate, and through alteration of benthic communities, and the reduction in prey availability. Therefore, we have determined that the proposed action would adversely affect the EFH identified above.

3.3. Essential Fish Habitat Conservation Recommendations

Fully implementing the EFH conservation recommendation below would protect, by avoiding or minimizing the adverse effects described in Section 3.2, above, approximately 900 square feet of designated EFH for Pacific Coast salmon.

1. To reduce adverse alteration of the physical, chemical, or biological characteristics of the water and substrate, the Corps should encourage the applicant to:
    - 1.1 Require their contractors to install full-depth silt curtains around in-water pile installation to minimize the spread of contaminated sediments.
    - 1.2 Require their contractors to adjust work practices to ensure that turbidity does not exceed 300 feet from the project site, and to halt work should the visible turbidity plume approach that range.

2. To reduce adverse alteration of benthic communities and reduction in prey availability, the Corps should require the applicant to:

2.1 Ensure that barges or other structures do not ground out on the bottom or anchor in submerged aquatic vegetation.

3.4. Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the Corps must provide a detailed response in writing to NMFS within 30 days after receiving an EFH Conservation Recommendation. Such a response must be provided at least 10 days prior to final approval of the action if the response is inconsistent with any of NMFS' EFH Conservation Recommendations unless NMFS and the Federal agency have agreed to use alternative time frames for the Federal agency response. The response must include a description of measures proposed by the agency for avoiding, minimizing, mitigating, or otherwise offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the Conservation Recommendations, the Federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)).

In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, NMFS established a quarterly reporting requirement to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we ask that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

3.5. Supplemental Consultation

The Corps 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 users of this opinion are the Corps. Other interested users could include marina owners and their agents, affected tribes, the Washington Department of Fish and Wildlife (WDFW), and the citizens of King County. Individual copies of this opinion were provided to the Corps. 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

Abatzoglou, J. T., Rupp, D. E., and Mote, P. W. (2014). Seasonal climate variability and change in the Pacific Northwest of the United States. *Journal of Climate, 27*(5), 2125-2142. doi:https://doi.org/10.1175/JCLI-D-13-00218.1

Anderson, J. J., Gurarie, E., and Zabel, R. W. (2005). Mean free-path length theory of predator–prey interactions: Application to juvenile salmon migration. *Ecological Modelling, 186*(2), 196-211. doi:10.1016/j.ecolmodel.2005.01.014

Bickel, S. L., Hammond, J. D. M., and Tang, K. W. (2011). Boat-generated turbulence as a potential source of mortality among copepods. *Journal of Experimental Marine Biology and Ecology, 401*, 105-109. doi:https://doi.org/10.1016/j.jembe.2011.02.038

Bloch, P. (2010). *SR 520 Test Pile Turbidity Monitoring Technical Memorandum*. Retrieved from Olympia, Washington:

Caltrans. (2015). *Technical guidance for assessment and mitigation of the hydroacoustic effects of pile driving on fish* (CTHWANP-RT-15-306.01.01). Retrieved from Sacramento, California: http://www.dot.ca.gov/hq/env/bio/files/bio_tech_guidance_hydroacoustic_effects_110215.pdf

Celedonia, M. T., Tabor, R. A., Sanders, S., Damm, S., Lantz, D. W., Lee, T. M., Li, Z., Pratt, J.-M., Price, B. E., and Seyda, L. (2008a). *Movement and habitat use of Chinook salmon smolts, northern pikeminnow, and smallmouth bass near the SR 520 Bridge: 2007 acoustic tracking study*. Retrieved from Lacy, Washington: https://www.wsdot.wa.gov/research/reports/fullreports/694.1.pdf

Celedonia, M. T., Tabor, R. A., Sanders, S., Lantz, D. W., and Grettenberger, I. (2008b). *Movement and habitat use of Chinook salmon smolts and two predatory fishes in Lake Washington and the Lake Washington ship canal: 2004-2005 acoustric tracking studies*. Retrieved from Lacey, Washington: https://www.fws.gov/wafwo/fisheries/Publications/2004_2005%20Acoustic%20Final%20Report.pdf

City of Seattle. (2008). *Synthesis of salmon research and monitoring: Investigations conducted in the western Lake Washington basin*. Retrieved from

City of Seattle. (2019). *Elliot Bay seawall project: 2018 post construction monitoring report (year 1)*. Retrieved from

Crozier, L. G., Hendry, A. P., Lawson, P. W., Quinn, T. P., Mantua, N. J., Battin, J., Shaw, R. G., and Huey, R. B. (2008). Potential responses to climate change in organisms with complex life histories: evolution and plasticity in Pacific salmon. *Evolutionary Applications, 1*(2), 252-270. doi:10.1111/j.1752-4571.2008.00033.x

Crozier, L. G., Scheuerell, M. D., and Zabel, E. W. (2011). Using time series analysis to characterize evolutionary and plastic responses to environmental change: A case study of a shift toward earlier migration date in sockeye salmon. *The American Naturalist, 178*(6), 755-773. doi:10.1086/662669

DNR. (2014). *Comparison of light transmitted through different types of decking used in nearshore over-water structures*. Retrieved from

Dolat, S. W. (1997). *Acoustic measurements during the Baldwin Bridge demolition*. Retrieved from Waterford, CT:

Dominguez, F., Rivera, E., Lettenmaier, D. P., and Castro, C. L. (2012). Changes in winter precipitation extremes for the western United States under a warmer climate as simulated by regional climate models. *Geophysical Research Letters, 39*(5). doi:https://doi.org/10.1029/2011GL050762

Doney, S. C., Ruckelshaus, M., Duffy, J. E., Barry, J. P., Chan, F., English, C. A., Galindo, H. M., Grebmeier, J. M., Hollowed, A. B., Knowlton, N., Polovina, J., Rabalais, N. N., Sydeman, W. J., and Talley, L. D. (2012). Climate Change Impacts on Marine Ecosystems. *Annual Review of Marine Science, 4*(11-37). doi:https://doi.org/10.1146/annurev-marine-041911-111611

Duncan, A. J., McCauley, R. D., Parnum, I., and Salgado-Kent, C. (2010). *Measurement and modelling of underwater noise from pile driving*. Retrieved from Sydney, Australia: https://www.acoustics.asn.au/conference_proceedings/ICA2010/cdrom-ICA2010/papers/p26.pdf

Ecology, W. D. o. (2018a). Gas Works Park WA Natural Gas: Site description. Retrieved from https://fortress.wa.gov/ecy/gsp/Sitepage.aspx?csid=2876

Ecology, W. S. D. o. (2018b). Washington State Coastal Atlas Map: Assessed sediments and assessed waters, Category 5 - 303(d). Retrieved from https://fortress.wa.gov/ecy/coastalatlas/tools/Map.aspx

Enger, P. S., Karlsen, H. E., Knudsen, F. R., and Sand, O. (1993). Detection and reaction of fish to infrasound. *ICES Marine Science Symposia, 196*, 108-112.

Feely, R. A., Klinger, T., Newton, J. A., and Chadsey, M. (2012). *Scientific summary of ocean acidification in Washington state marine waters*. (Special Report). Retrieved from https://pmel.noaa.gov/co2/files/wa_shellfish_initiative_blue_ribbon_panel_oa_11-27-2012.pdf

Fisheries Hydroacoustic Working Group. (2008). *Agreement in principle for interim criteria for injury to fish from pile driving activities*. Retrieved from https://www.wsdot.wa.gov/sites/default/files/2018/01/17/ENV-FW-BA_InterimCriteriaAgree.pdf

Glick, P., Clough, J., and Nunley, B. (2007). Sea-Level Rise and Coastal Habitats in the Pacific Northwest: An analysis for Puget Sound, southwestern Washington, and northwestern Oregon. from National Wildlife Federation https://www.nwf.org/~/media/PDFs/Water/200707_PacificNWSeaLevelRise_Report.ashx

Goode, J. R., Buffington, J. M., Tonina, D., Isaak, D. J., Thurow, R. F., Wenger, S., Nagel, D., Luce, C., Tetzlaff, D., and Soulsby, C. (2013). Potential effects of climate change on streambed scour and risks to salmonid survival in snow-dominated mountain basins. *Hydrological Processes, 27*(5), 750-765. doi:https://doi.org/10.1002/hyp.9728

Hellou, J., and Payne, J. F. (1986). Effect of petroleum hydrocarbons on the biliary bile acid composition of rainbow trout (*Salmo gairdneri*). *Comparative Biochemistry and Physiology Part C: Comparative Pharmacology, 84*(2), 257–261. doi:https://doi.org/10.1016/0742-8413(86)90091-5

Hicks, B. J., Hall, J. D., Bisson, P. A., and Sedell, J. R. (1991). Responses of salmonids to habitat change. In W. R. Meehan (Ed.), *Influences of Forest and Rangeland Management on Salmonid Habitat: American Fisheries Society Special Publication* (Vol. 19, pp. 483-518). Bethesda, Maryland: American Fisheries Society.

IPCC, I. P. o. C. C. (2014). *Climate Change 2014: Synthesis Report*. Retrieved from Geneva, Switzerland: http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf

Isaak, D. J., Wollrab, S., Horan, D., and Chandler, G. (2012). Climate change effects on stream and river temperatures across the northwest US from 1980–2009 and implications for salmonid fishes. *Climatic Change, 113*(2), 499-524. doi:10.1007/s10584-011-0326-z

ISAB, I. S. A. B. (2007). *Climate change impacts on Columbia River Basin fish and wildlife*. Retrieved from Portland, Oregon: https://www.nwcouncil.org/fish-and-wildlife/fw-independent-advisory-committees/independent-scientific-advisory-board/climate-change-impacts-on-columbia-river-basin-fish-and-wildlife

Karrow, N., Boermans, H. J., Dixon, D. G., Hontella, A., Soloman, K. R., White, J. J., and Bols, N. C. (1999). Characterizing the immunotoxicity of creosote to rainbow trout (*Oncorhynchus mykiss*): A microcosm study. *Aquatic Toxicology, 45*, 223-239.

Kemp, P. S., Gessel, M. H., and Williams, J. G. (2005). Seaward migrating subyearling Chinook salmon avoid overhead cover. *Journal of Fish Biology, 67*. doi:https://doi.org/10.1111/j.0022-1112.2005.00833.x

Killgore, K. J., Miranda, L. E., Murphy, C. E., Wolff, D. M., Hoover, J. J., Keevin, T. M., Maynord, S. T., and Cornish, M. A. (2011). Fish entrainment rates through towboat propellers in the upper Mississippi and Illinois Rivers. *Transactions of the American Fisheries Society, 140*(3), 570-581. doi:https://doi.org/10.1080/00028487.2011.581977

Knudsen, F. R., Schreck, C. B., Knapp, S. M., Enger, P. S., and Sand, O. (1997). Infrasound produces flight and avoidance responses in Pacific juvenile salmonids. *Journal of Fish Biology, 51*, 824-829. doi:https://doi.org/10.1111/j.1095-8649.1997.tb02002.x

Kunkel, K. E., Stevens, L. E., Stevens, S. E., Sun, L., Janssen, E., Wuebbles, D., Redmond, K. T., and Dobson, J. G. (2013). *Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 6*. (NESDIS 142-6). Washington, D.C. Retrieved from https://scenarios.globalchange.gov/sites/default/files/NOAA_NESDIS_Tech_Report_142-6-Climate_of_the_Northwest_U.S_0.pdf

Landrum, P. F., Eadie, B. J., Faust, W. R., Morehead, N. R., and McCormick, M. J. (1984). *Role of sediment in the bioaccumulation of benzo(a)pyrene by the amphipod, Pontoporeia hoyi*. Columbus, Ohio: Battelle Press.

Landrum, P. F., and Scavia, D. (1983). Influence of sediment on anthracene uptake, depuration, and biotransformation by the amphipod *Hyalella azteca*. *Canadian Journal of Fisheries and Aquatic Sciences, 40*, 298-305. doi:https://doi.org/10.1139/f83-044

Lawson, P. W., Logerwell, E. A., Mantua, N. J., Francis, R. C., and Agostini, V. N. (2004). Environmental factors influencing freshwater survival and smolt production in Pacific Northwest coho salmon (*Oncorhynchus kisutch*). *Canadian Journal of Fisheries and Aquatic Sciences, 61*(3), 360-373.

Lee, R., and Dobbs, G. (1972). Uptake, metabolism and discharge of polycyclic aromatic hydrocarbons by marine fish. *Marine Biology, 17*, 201-208. doi:https://doi.org/10.1007/BF00366294

Mantua, N., Tohver, I., and Hamlet, A. (2009). Impacts of Climate Change on Key Aspects of Freshwater Salmon Habitat in Washington State. In J. L. M.M. Elsner, L. Whitely Binder (Ed.), *The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate* (pp. 217-253). Seattle, Washington: The Climate Impacts Group, University of Washington.

Mantua, N., Tohver, I., and Hamlet, A. (2010). Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. *Climatic Change, 102*(1), 187-223. doi:https://doi.org/10.1007/s10584-010-9845-2

MarineTraffic. (2019). Vessels database Lake Union. Retrieved from https://www.marinetraffic.com/en/ais/home/centerx:-122.337/centery:47.637/zoom:14

Marshall, A. R., Small, M., and Foley, S. (2004). *Genetic relationships among anadromous and non-anadromous Oncorhynchus mykiss in Cedar River and Lake Washington: Implications for steelhead recovery planning*. Olympia and Mill Creek, WA: Progress Report to Cedar River Anadromous Fish Committee and Seattle Public Utilities Retrieved from https://wdfw.wa.gov/publications/01426/wdfw01426.pdf

McCain, B., Malins, D. C., Krahn, M. M., Brown, D. W., Gronlund, W. D., Moore, L. K., and Chan, S.-L. (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. doi:https://doi.org/10.1007/BF01059807

McMahon, T. E., and Hartman, G. F. (1989). Influence of cover complexity and current velocity on winter habitat use by juvenile coho salmon (*Oncorhynchus kisutch*). *Canadian Journal of Fisheries and Aquatic Sciences, 46*(9), 1551-1557. doi:https://doi.org/10.1139/f89-197

Meador, J. P., Sommers, F. C., Ylitalo, G. M., and Sloan, C. A. (2006). Altered growth and related physiological responses in juvenile Chinook salmon (*Oncorhynchus tshawytscha*) from dietary exposure to polycyclic aromatic hydrocarbons (PAHs). *Canadian Journal of Fisheries and Aquatic Sciences, 63*, 2364-2376. doi:https://doi.org/10.1139/f06-127

Meyer, J. L., Sale, M. J., Mulholland, P. J., and Poff, N. L. (1999). Impacts of climate change on aquatic ecosystem functioning and health. *JAWRA Journal of the American Water Resources Association, 35*(6), 1373-1386. doi:10.1111/j.1752-1688.1999.tb04222.x

Moore, M. E., Berejikian, B. A., and Tezak, E. P. (2013). A floating bridge disrupts seaward migration and increases mortality of steelhead smolts in Hood Canal, Washington State. *PLoS One, 8*(9). doi:https://doi.org/10.1371/journal.pone.0073427

Morton, J. W. (1976). *Ecological effects of dredging and dredge spoil disposal: a literature review*. Retrieved from Washington, DC: https://babel.hathitrust.org/cgi/pt?id=mdp.39015086512640;view=1up;seq=7

Mote, P. W., Abatzoglou, J. T., and Kunkel, K. E. (2013). Climate: Variability and Change in the Past and the Future. In P. W. M. M.M. Dalton, and A.K. Snover (Ed.), *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities*. Washington D.C.: Island Press.

Mote, P. W., Rupp, D. E., Li, S., Sharp, D. J., Otto, F., Uhe, P. F., Xiao, M., Lettenmaier, D. P., Cullen, H., and Allen, M. R. (2016). Perspectives on the cause of exceptionally low 2015 snowpack in the western United States. *Geophysical Research Letters, 43*, 10980-11098. doi:https://doi.org/10.1002/2016GL069965

Mote, P. W., Snover, A. K., Capalbo, S., Eigenbrode, S. D., Glick, P., Littell, J., Raymondi, R. R., and Reeder, W. S. (2014). Northwest. In T. C. R. J. M. Melillo, and G.W. Yohe (Ed.), *Climate Change Impacts in the United States: The Third National Climate Assessment* (pp. 487-513): U.S. Global Change Research Program.

Munsch, S. H., Cordell, J. R., Toft, J. D., and Morgan, E. E. (2014). Effects of seawalls and piers on fish assemblages and juvenile salmon feeding behavior. *North American Journal of Fisheries Management, 34*(4), 814-827. doi:http://dx.doi.org/10.1080/02755947.2014.910579

Neff, J. M. (1982). *Accumulation and release of polycyclic aromatic hydrocarbons from water, food, and sediment by marine animals*. (600/9-82-013). N.L. Richards and B.L. Jackson (eds.) Retrieved from https://nepis.epa.gov/Exe/ZyPDF.cgi/9101R2QQ.PDF?Dockey=9101R2QQ.PDF

Neff, J. M., Cox, B. A., Dixit, D., and Anderson, J. W. (1976). Accumulation and release of petroleum-derived aromatic hydrocarbons by four species of marine animals. *Marine Biology, 38*(3), 279-289. doi:https://doi.org/10.1007/BF00388940

Nightingale, B., and Simenstad, C. A. (2001). *Overwater Structures: Marine Issues*. Retrieved from Washington State Transportation Center: https://wdfw.wa.gov/publications/00051/wdfw00051.pdf

Niimi, A. J., and Dookhran, G. P. (1989). Dietary absorption efficiencies and elimination rates of polycyclic aromatic hydrocarbons (PAHs) in rainbow trout (*Salmo gairdneri*). *Environmental Toxicology and Chemistry, 8*, 719-722. doi:https://doi.org/10.1002/etc.5620080809

Niimi, A. J., and Palazzo, V. (1986). Biological half-lives of eight polycyclic aromatic hydrocarbons (PAHs) in rainbow trout (*Salmo gairdneri*). *Water Research, 20*, 503-507. doi:https://doi.org/10.1016/0043-1354(86)90200-9

NMFS. (2006). *Final supplement to the Shared Strategy's Puget Sound salmon recovery plan*. Seattle, Washington Retrieved from https://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/puget_sound/chinook/ps-supplement.pdf

NWFSC, N. F. S. C. (2015). *Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest*. Retrieved from https://www.nwfsc.noaa.gov/assets/11/8623_03072016_124156_Ford-NWSalmonBioStatusReviewUpdate-Dec%2021-2015%20v2.pdf

Ono, K., Simenstad, C. A., Toft, J. D., Southard, S. L., Sobocinski, K. L., and Borde, A. (2010). *Assessing and mitigating dock shading impacts on the behavior of juvenile pacific salmon (Oncorhyncus spp.): Can artificial light mitigate the effects*. Retrieved from https://www.wsdot.wa.gov/research/reports/fullreports/755.1.pdf

PFMC, P. F. M. C. (2014). *Appendix A to the Pacific Coast Salmon Fishery Management Plan, as modified by Amendment 18 to the Pacific Coast Salmon Plan: Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon*. Retrieved from Portland, Oregon: https://www.westcoast.fisheries.noaa.gov/publications/habitat/essential_fish_habitat/salmon_efh_appendix_a_final_september-25_2014__2_.pdf

Raymondi, R. R., Cuhaciyan, J. E., Glick, P., Capalbo, S. M., Houston, L. L., Shafer, S. L., and Grah, O. (2013). Water Resources: Implications of Changes in Temperature and Precipitation. In P. W. M. M.M. Dalton, and A.K. Snover (Ed.), *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities* (pp. 41-58). Washington, D.C.: Island Press.

Reeder, W. S., Ruggiero, P. R., Shafer, S. L., Snover, A. K., Houston, L. L., Glick, P., Newton, J. A., and Capalbo, S. M. (2013). Coasts: Complex Changes Affecting the Northwest's Diverse Shorelines. In P. W. M. M.M. Dalton, and A.K. Snover (Ed.), *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities* (pp. 41-58). Washington, DC: Island Press.

Romberg, P. (2005). *Recontamination Sources at Three Sediment Caps in Seattle*. Retrieved from https://your.kingcounty.gov/dnrp/library/wastewater/sedman/Denny/Denny_200506.pdf

Roubal, W. T., Collier, T. K., and Malins, D. C. (1977). Accumulation and metabolism of carbon-14 labeled benzene, naphthalene, and anthracene by young Coho salmon (*Oncorhynchus kisutch*). *Archives of Environmental Contamination and Toxicology, 5*, 513-529. doi:https://doi.org/10.1007/BF02220929

Sand, O., Enger, P. S., Karlsen, H. E., Knudsen, F., and Kvernstuen, T. (2000). Avoidance responses to infrasound in downstream migrating European silver eels, *Anguilla anguilla*. *Environmental Biology of Fishes, 57*, 327-336. doi:https://doi.org/10.1023/A:1007575426155

Scheuerell, M. D., and Williams, J. G. (2005). Forecasting climate-induced changes in the survival of Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha*). *Fisheries Oceanography, 14*(6), 448-457. doi:http://dx.doi.org/10.1111/j.1365-2419.2005.00346.x

Simenstad, C. A., Nightingale, B. J., Thom, R. M., and Shreffler, D. K. (1999). *Impacts of ferry terminals on juvenile salmon migrating along Puget Sound shorelines*. Retrieved from Olympia, Washington: http://depts.washington.edu/trac/bulkdisk/pdf/272.1.pdf

Smith, P. T. (2008). Risks to human health and estuarine ecology posed by pulling out creosote-treated timber on oyster farms. *Aquatic Toxicology, 86*(2), 287-298. doi:https://doi.org/10.1016/j.aquatox.2007.11.009

Southard, S. L., Thom, R. M., Williams, G. D., Toft, T. J. D., May, C. W., McMichael, G. A., Vucelick, J. A., Newell, J. T., and Southard, J. A. (2006). *Impacts of ferry terminals on juvenile salmon movement along Puget Sound shorelines*. Retrieved from https://rosap.ntl.bts.gov/view/dot/16233/dot_16233_DS1.pdf

SSDC, S. S. D. C. (2007). *Puget Sound salmon recovery plan*. Retrieved from https://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/puget_sound/chinook/pugetsoundchinookrecoveryplan_wo_exec_summary.pdf

Stadler, J. H., and Woodbury, D. P. (2009). *Assessing the effects to fishes from pile driving: Application of new hydroacoustic criteria*. Paper presented at the inter-noise 2009, Ottawa, CA. ftp://ftp.odot.state.or.us/techserv/geo-environmental/Biology/Hydroacoustic/References/Literature%20references/Stadler%20and%20Woodbury%202009.%20%20Assessing%20the%20effects%20to%20fishes%20from%20pile%20driving.pdf

Statham, C. N., Elcombe, C. R., Szyjka, S. P., and Lech, J. J. (1978). Effect of polycyclic aromatic hydrocarbons on hepatic, microsomal enzymes and disposition on methylnaphthalene in rainbow trout *in vivo*. *Xenobiotica, 8*(2), 65-71. doi:https://doi.org/10.3109/00498257809060385

Suedel, B. C., Boraczek, J. A., Peddicord, R. K., Clifford, P. A., and Dillon, T. M. (1994). Trophic transfer and biomagnification potential of contaminants in aquatic ecosystems. *Reviews of Environmental Contamination and Toxicology, 136*, 22-89. doi:10.1007/978-1-4612-2656-7_2

Sunda, W. G., and Cai, W. J. (2012). Eutrophication induced CO2-acidification of subsurface coastal waters: interactive effects of temperature, salinity, and atmospheric pCO2. *Environmental Science & Technology, 46*(19), 10651-10659. doi:10.1021/es300626f

Tague, C. L., Choate, J. S., and Grant, G. (2013). Parameterizing sub-surface drainage with geology to improve modeling streamflow responses to climate in data limited environments. *Hydrology and Earth System Sciences, 17*(1), 341-354. doi:https://doi.org/10.5194/hess-17-341-2013

Tillmann, P., and Siemann, D. (2011). *Climate Change Effects and Adaptation Approaches in Marine and Coastal Ecosystems of the North Pacific Landscape Conservation Cooperative Region*. Retrieved from https://www.nwf.org/~/media/PDFs/Global-Warming/2014/Marine-Report/NPLCC_Marine_Climate-Effects_Final.pdf

Varanasi, U., Casillas, E., Arkoosh, M. R., Hom, T., Misitano, D. A., Brown, D. W., Chan, S. L., Collier, T. K., McCain, B. B., and Stein, J. E. (1993). *Contaminant exposure and associated biological effects in juvenile Chinook salmon (Oncorhynchus tshawytscha) from urban and nonurban estuaries of Puget Sound*. (NMFS-NWFSC-8). Seattle, WA: NMFS NFSC Retrieved from https://www.nwfsc.noaa.gov/publications/scipubs/techmemos/tm8/tm8.html

Varanasi, U., Stein, J. E., and Nishimoto, M. (1989). Biotransformation and disposition of polycyclic aromatic hydrocarbons in fish. In U. Varanasi (Ed.), *Metabolism of Polycyclic Aromatic Hydrocarbons in the Aquatic Environment* (pp. 93-149). Boca Raton, Florida: CRC Press.

Veirs, S., Veirs, V., and Wood, J. D. (2016). Ship noise extends to frequencies used for echolocation by endangered killer whales. *PeerJ, 4*, e1657. doi:https://doi.org/10.7717/peerj.1657

Wainwright, T. C., and Weitkamp, L. A. (2013). Effects of climate change on Oregon Coast coho salmon: habitat and life-cycle interactions. *Northwest Science, 87*(3), 219-242. doi:https://doi.org/10.3955/046.087.0305

WDFW. (2019a). *Puget Sound final abundance Chinook*. Retrieved from: https://data.wa.gov/dataset/Puget-Sound-Final-Abundance-Chinook-11152012/xzqf-dbht/data

WDFW. (2019b). *Puget Sound final abundance steelhead*. Retrieved from: https://data.wa.gov/dataset/Puget-Sound-Final-Abundance-Steelhead-10222012/w4dt-5axg/data

Werme, C., Hunt, J., Beller, E., Cayce, K., Klatt, M., Melwani, A., Polson, E., and Grossinger, R. (2010). *Removal of Creosote-Treated Pilings and Structures from San Francisco Bay*. Retrieved from Oakland, California: https://www.sfei.org/sites/default/files/ReportNo605_Creosote_Dec2010_finalJan13.pdf

Willette, T. M. (2001). Foraging behaviour of juvenile pink salmon (*Oncorhynchus gorbuscha*) and size-dependent predation risk. *Fisheries Oceanography*, *10*(1), 110-131. doi:https://doi.org/10.1046/j.1054-6006.2001.00042.x

Winder, M., and Schindler, D. E. (2004). Climate change uncouples trophic interactions in an aquatic ecosystem. *Ecology*, *85*, 2100–2106. doi:https://doi.org/10.1890/04-0151

Zabel, R. W., Scheuerell, M. D., McClure, M. M., and Williams, J. G. (2006). The Interplay between Climate Variability and Density Dependence in the Population Viability of Chinook Salmon. *Conservation Biology*, *20*(1), 190-200. doi:http://dx.doi.org/10.1111/j.1523-1739.2005.00300.x