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 97232-1274

Refer to NMFS No.:
WCRO-2023-03223 (Barge 30)
WCRO-2024-00354 (Barge 513)

May 6, 2025

P. Allen Atkins
Chief, Regulatory Branch
Department of the Army
U.S. Army Corps of Engineers, Seattle District
4735 East Marginal Way South, BLDG 1202
Seattle, Washington 98134-2388

Re: Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Tidewater Industrial Center Spud Barge 30 Replacement (Swap) (USACE No.: NWS-2023-865) and Tidewater Barge Lines, Inc. Spud Barge 513 Replacement (Swap) (USACE No.: NWS-2023-886)

Dear Mr. Atkins:

Thank you for your letters of December 22, 2023 and February 16, 2024 requesting initiation of consultation with NOAA's National Marine Fisheries Service (NMFS) pursuant to section 7 of the Endangered Species Act of 1973 (ESA) (16 U.S.C. 1531 et seq.) for the U.S. Army Corps of Engineers' (Corps) authorization of the Tidewater Industrial Center Spud Barge 30 Replacement and the Tidewater Barge Lines, Inc. Spud Barge 513 Replacement projects, located in the Columbia River near river mile (RM) 102.5 and 76, respectively.

Thank you also for your request for essential fish habitat (EFH) consultation. NMFS reviewed the proposed action for potential effects on EFH pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), implementing regulations at 50 CFR 600.920, and agency guidance for use of the ESA consultation process to complete EFH consultation.

The enclosed document contains the biological opinion (opinion) prepared by NMFS pursuant to section 7 of the ESA on the effects of the proposed action. In this opinion, NMFS concludes that for the proposed actions:

Barge 30 is not likely to jeopardize the continued existence of and is not likely to result in the destruction or adverse modification of critical habitat designated for the following species:

- Chinook Salmon *(Oncorhynchus tshawytscha)*
  - Lower Columbia River (LCR) Chinook salmon
  - Upper Willamette River (UWR) Chinook salmon
  - Upper Columbia River (UCR) spring-run Chinook salmon
  - Snake River (SR) spring/summer-run Chinook salmon
  - SR fall-run Chinook salmon

- LCR coho salmon (*O. kisutch)*
- Columbia River (CR) chum salmon (*O. keta)*
- SR sockeye salmon (*O. nerka)*
- Steelhead (*O. mykiss*);
    - LCR steelhead
    - UWR steelhead
    - Middle Columbia River (MCR) steelhead
    - UCR steelhead
    - Snake River Basin (SRB) steelhead
- Southern DPS of Pacific Eulachon (*Thaleichthys pacificus*)

Barge 513 is not likely to jeopardize the continued existence of and is not likely to result in the destruction or adverse modification of critical habitat designated for the following species:

- Chinook Salmon *(Oncorhynchus tshawytscha)*;
    - LCR Chinook salmon
    - UCR spring-run Chinook salmon
    - SR spring/summer-run Chinook salmon
    - SR fall-run Chinook salmon
- LCR coho salmon (*O. kisutch)*
- CR chum salmon (*O. keta)*
- SR sockeye salmon (*O. nerka)*
- Steelhead (*O. mykiss*);
    - LCR steelhead
    - MCR steelhead
    - UCR steelhead
    - SRB steelhead
- Southern DPS of Pacific Eulachon (*Thaleichthys pacificus*)

NMFS concurred with the Corps' determination that the proposed actions are not likely to adversely affect the following species or their designated critical habitat:

- Southern DPS of green sturgeon (*Acipenser medirostris*) (hereafter also referred to as green sturgeon)

This opinion includes an incidental take statement (ITS) that describes reasonable and prudent measures (RPMs) NMFS considers necessary or appropriate to minimize the incidental take associated with this action, and sets forth nondiscretionary terms and conditions that the Corps and the applicant must comply with to meet those measures. Incidental take from actions that meet these terms and conditions will be exempt from the ESA's prohibition against the take of listed species.

NMFS also reviewed the likely effects of the proposed action on essential fish habitat (EFH), pursuant to section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), implementing regulations at 50 CFR 600.920, and agency guidance for use of the ESA consultation process to complete EFH consultation. We have concluded that the action would adversely affect EFH designated under the Pacific Coast salmon and Pacific Coast groundfish. Therefore, we have included the results of that review in Section 3 of this document.

Please contact Curtis McFeron in Lacey, Washington, at curtis.mcferon@noaa.gov, or (253)-693-0946, if you have any questions concerning this consultation, or if you require additional information.

Sincerely,

Kathleen Wells
Assistant Regional Administrator
Oregon Washington Coastal Office

cc: Joshua Sindel, Project Manager, USACE
Owen Weller, Project Manager, USACE

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

Tidewater Industrial Center Barge Replacement, Clark County
and
Tidewater Barge Line, Inc. Barge Replacement, Cowlitz County

NMFS Consultation Number: WCRO-2023-03223 (Columbia River, RM 102.5)
WCRO-2024-00354 (Columbia River, RM 76)

Action Agency: U.S. Army Corps of Engineers

Affected Species and NMFS' Determinations:

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species?	If likely to adversely affect, Is Action Likely to Jeopardize the Species?	Is Action Likely to Adversely Affect Critical Habitat?	If likely to adversely affect, is Action Likely to Destroy or Adversely Modify Critical Habitat?
Snake River steelhead	Threatened	Yes	No	Yes	No
Lower Columbia River steelhead	Threatened	Yes	No	Yes	No
Middle Columbia River steelhead	Threatened	Yes	No	Yes	No
Upper Columbia River steelhead	Threatened	Yes	No	Yes	No
Upper Willamette River steelhead	Threatened	Yes/No[1]	No	Yes	No
Upper Columbia River Spring-Run	Endangered	Yes	No	Yes	No
Lower Columbia River Chinook salmon	Threatened	Yes	No	Yes	No
Upper Willamette River Chinook salmon	Threatened	Yes/No[1]	No	Yes	No
Snake River spring/summer Chinook	Threatened	Yes	No	Yes	No
Snake River fall-run Chinook salmon	Threatened	Yes	No	Yes	No
Columbia River chum	Threatened	Yes	No	Yes	No
Lower Columbia River coho salmon	Threatened	Yes	No	Yes	No
Snake River sockeye Salmon	Endangered	Yes	No	Yes	No
Southern DPS eulachon	Threatened	Yes	No	Yes	No

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	Yes

[1] Barge 30 (WCRO-2023-03223) is not likely to adversely affect the Upper Willamette species, as species and critical habitat presence do not intersect with the Action area.

Consultation Conducted By: National Marine Fisheries Service
West Coast Region

Issued By:

Kathleen Wells
Assistant Regional Administrator
Oregon Washington Coastal Office

Date: May 6, 2025

TABLE OF CONTENTS

1. INTRODUCTION

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

1.1. Background

The National Marine Fisheries Service (NMFS) 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.), as amended, and implementing regulations at 50 CFR part 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 part 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). The document will be available at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. A complete record of this consultation is on file at the Oregon Washington Coastal Office located in Lacey, Washington.

Updates to the regulations governing interagency consultation (50 CFR part 402) were effective on May 6, 2024 (89 Fed. Reg. 24268). We are applying the updated regulations to this consultation. The 2024 regulatory changes, like those from 2019, were intended to improve and clarify the consultation process, and, with one exception from 2024 (offsetting reasonable and prudent measures), were not intended to result in changes to the Services' existing practice in implementing section 7(a)(2) of the Act. 89 Fed. Reg. at 24268; 84 Fed. Reg. at 45015. We have considered the prior rules and affirm that the substantive analysis and conclusions articulated in this biological opinion and incidental take statement would not have been any different under the 2019 regulations or pre-2019 regulations.

1.2. Consultation History

This biological opinion contains information and analysis for two proposed actions for replacement (swaps) of spud barges – Vancouver Spud Barge 30 and Kalama Spud Barge 513.

Vancouver Spud Barge 30
On December 26, 2023, NMFS received a request for informal consultation from the U.S. Army Corps of Engineers (Corps), on behalf of the applicant Tidewater Industrial Center, with submitted materials including a Biological Assessment (BA) and site drawings.

On March 19, 2025, NMFS determined the project actions required formal consultation and requested through the Corps if the applicant wished to proceed with a formal consultation.

NMFS also reviewed the likely effects of the proposed action on EFH, and determined that the action would adversely affect the EFH of Pacific Coast salmon and Pacific Coast groundfish.

On March 20, 2025, the Corps confirmed, and NMFS initiated, formal consultation for the project.

Further email exchange is as follows:

- On March 26 and April 24, 2025, the applicant responded to our requests for more information regarding where the removed Barge (#30) would be relocated.

<u>Kalama Barge 513</u>
On February 16, 2024, NMFS received a request for informal consultation from the U.S. Army Corps of Engineers (Corps), on behalf of the applicant Tidewater Barge Lines, Inc., with submitted materials including a Biological Assessment (BA) and site drawings.

On March 28, 2025, NMFS determined the project actions required formal consultation and requested through the Corps if the applicant wished to proceed with a formal consultation. In addition, NMFS approached USACE to combine similar barge replacement projects into a single batched consultation. This request to batch the two consultations into a combined formal acknowledged by the Corps on April 1, 2025.

NMFS also reviewed the likely effects of the proposed action on EFH, and determined that the action would adversely affect the EFH of Pacific Coast salmon and Pacific Coast groundfish.

This opinion is based on the information in the documents and emails identified above; recovery plans, status reviews, and critical habitat designations for ESA-listed species; published and unpublished scientific information on the biology and ecology of those species; and relevant scientific and gray literature (see References).

1.3. Proposed Federal Action

Under the ESA, “action” means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by federal agencies (see 50 CFR 402.02). Under the MSA, “federal action” means any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken by a federal agency (see 50 CFR 600.910).

<u>Spud Barge 30</u>
The Corps is proposing to authorize the replacement of Tidewater’s Spud Barge 30 along the Washington side of the Lower Columbia River (LCR), in Vancouver, Washington, with a larger Spud Barge 803. Located approximately at LCR’s river mile (RM) 102.5, Tidewater has staged a spud barge in the intertidal zone at this location to moor tugboats and provide a place to maintain and repair its tugboat fleet. It is connected to Tidewater’s barge maintenance dock by an approximately 91-foot gangway suspended over the shoreline. Barge 30 measures 6,760 square feet (sf) and the replacement, Barge 803, measures 8,800 sf, an increase of 2,040 sf.

Barge 30 will be relocated approximately 0.66 mile downriver to Matthews Point where it will be moored to Tidewater's Matthews Point Spud Barge, within the intertidal zone along the Washington side of LCR, for an indefinite amount of time (Figure 1).

The project will entail the following chronological actions:

- Move tugboats moored at Barge 30;
- Remove the three spuds holding Barge 30 in place with a crane (atop a crane barge);
- Move Barge 30 to Matthews Point with a tugboat, where it will be moored;
- Move Barge 803 into place (generally over the same footprint of Barge 30) with a tugboat;
- Lowering three spuds to affix Barge 803 into place with a crane (mounted on a crane barge); spuds will be dropped into place, with no pile-driving activities.

The project is anticipated to take one to two days to complete. The BA detailed that the Washington Department of Fish & Wildlife (WDFW) does not require an in-water work window for the project. The BA also detailed the applicant's use of current BMPs, guided by state and federal regulations, to minimize impacts to habitats and species that may potentially occur in the vicinity of the project area.

Spud Barge 513

The Corps is proposing to authorize the replacement of Tidewater's Spud Barge 513 along the Washington side of the LCR, in Kalama, Washington, with the larger Spud Barge 551. Currently, Spud Barge 551 is moored at Portland Harbor, in the intertidal zone, along the Oregon side of the LCR. Spud Barge 513 will be moored at the same location as 551, in Portland Harbor, for an indefinite amount of time. The Kalama location for each barge, at RM 76 on the LCR, is in deep water, approximately 200 feet from the shoreline. The replacement barge will provide more secure anchoring (having three spuds rather than two) in this reach of the CR that has more wind and higher waves than other river reaches. (See Figure 2.)

The project will entail the following actions:

- Remove the three spuds anchoring Barge 551 at Portland Harbor with a crane (atop a crane barge);
- Move Barge 551 to Kalama with a tugboat (approximately 68 miles downstream);
- Remove the two spuds anchoring Barge 513 at Kalama with a crane;
- Replace barge 513 with 551, by lowering the three spuds on Barge 551 with a crane (atop a crane barge) - spuds will be dropped into place, with no pile-driving activities;
- Move Barge 513 to Portland Harbor and anchor it with its two spuds in the same location as Barge 551; spuds will be dropped into place, with no pile-driving activities.

The project is anticipated to take one to two days to complete. The BA detailed that WDFW does not require an in-water work window for the project. The BA also detailed the applicant's use of current BMPs, guided by state and federal regulations, to minimize impacts to habitats and species that may potentially occur in the vicinity of the project area.

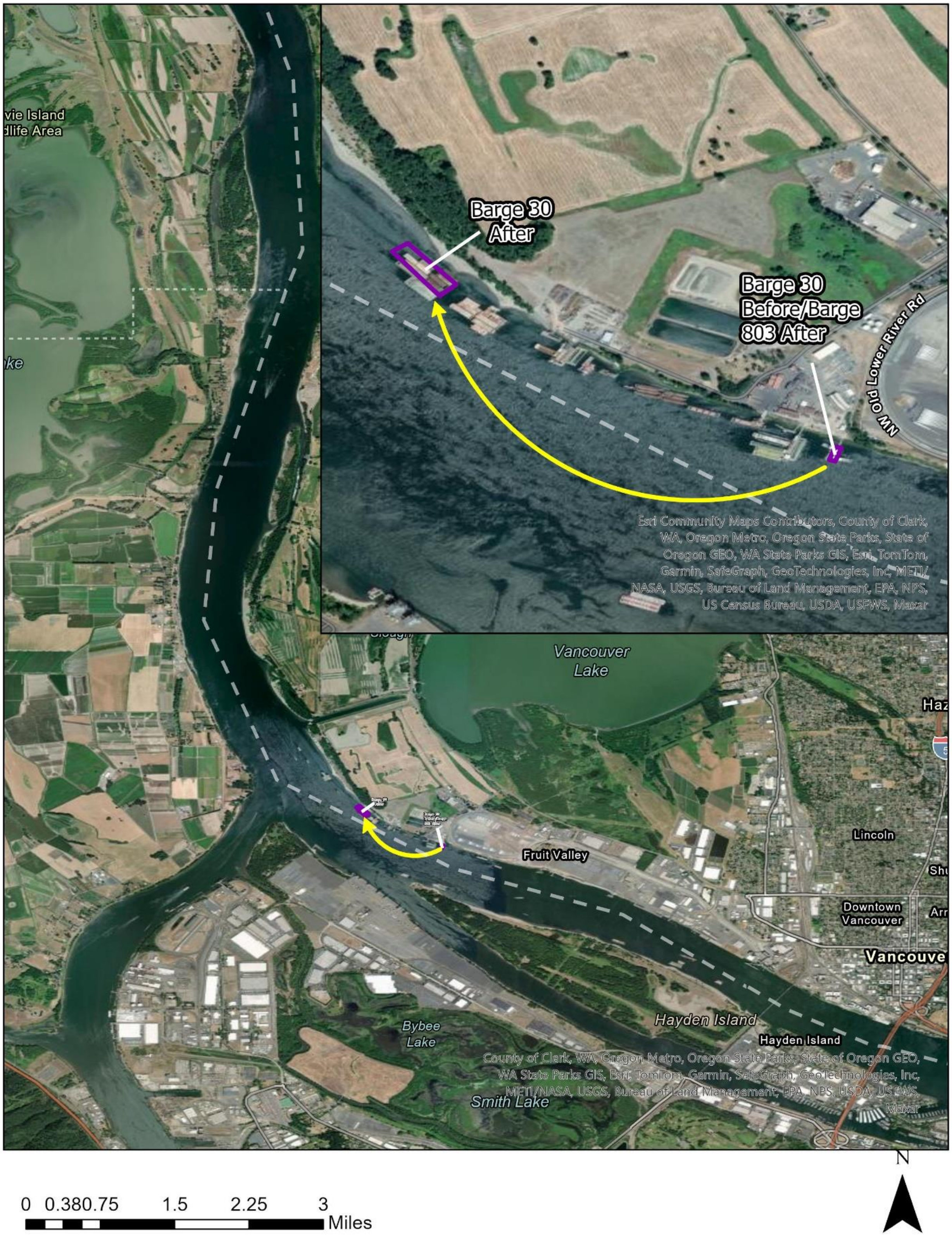

Figure 1 Tidewater Barge 30 Replacement and Relocation in the Columbia River.

Figure 2. Tidewater Barge 513 Replacement and Relocation on the Columbia River.

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 to 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 provide 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 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 an adverse modification analysis. The jeopardy analysis relies upon the regulatory definition of "jeopardize the continued existence of" a listed species, which is "to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of 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 also relies on the regulatory definition of "destruction or adverse modification," which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species" (50 CFR 402.02).

The designations of critical habitat for the species analyzed herein use the term primary constituent element (PCE) or essential features. The 2016 final rule (81 FR 7414; February 11, 2016) that revised the critical habitat regulations (50 CFR 424.12) replaced 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.

The ESA Section 7 implementing regulations define effects of the action using the term "consequences" (50 CFR 402.02). As explained in the preamble to the final rule revising the definition and adding this term (84 FR 44976, 44977; August 27, 2019), that revision does not change the scope of our analysis, and in this opinion, we use the terms "effects" and "consequences" interchangeably.

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

- Evaluate the rangewide status of the species and critical habitat expected to be adversely affected by the proposed action.
- Evaluate the environmental baseline of the species and critical habitat.
- Evaluate the effects of the proposed action on species and their critical habitat using an exposure–response approach.
- Evaluate cumulative effects.
- In the integration and synthesis, add the effects of the action and cumulative effects to the environmental baseline, and, in light of the status of the species and critical habitat, analyze whether the proposed action is likely to: (1) directly or indirectly 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; or (2) directly or indirectly result in an alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species.
- If necessary, suggest a reasonable and prudent alternative 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. Major ecological realignments are already occurring in response to climate change (IPCC WGII, 2022).

Long-term trends in warming have continued at global, national and regional scales. Global surface temperatures in the last decade (2010s) were estimated to be 1.09 °C higher than the 1850-1900 baseline period, with larger increases over land ~1.6 °C compared to oceans ~0.88 (IPCC WGI, 2021). The vast majority of this warming has been attributed to anthropogenic releases of greenhouse gases (IPCC WGI, 2021). Globally, 2014-2018 were the 5 warmest years on record both on land and in the ocean (2018 was the 4th warmest) (NOAA NCEI 2022). Events such as the 2013-2016 marine heatwave (Jacox et al. 2018) have been attributed directly to anthropogenic warming in the annual special issue of Bulletin of the American Meteorological Society on extreme events (Herring et al. 2018). Global warming and anthropogenic loss of biodiversity represent profound threats to ecosystem functionality (IPCC WGII 2022). These two factors are often examined in isolation, but likely have interacting effects on ecosystem function.

Updated projections of climate change are similar to or greater than previous projections (IPCC WGI, 2021). NMFS is increasingly confident in our projections of changes to freshwater and marine systems because every year brings stronger validation of previous predictions in both physical and biological realms. Retaining and restoring habitat complexity, access to climate refuges (both flow and temperature) and improving growth opportunity in both freshwater and marine environments are strongly advocated in the recent literature (Siegel and Crozier 2020).

Climate change is systemic, influencing freshwater, estuarine, and marine conditions. Other systems are also being influenced by changing climatic conditions. Literature reviews on the impacts of climate change on Pacific salmon (Crozier 2014, 2016, 2017, Crozier and Siegel 2018, Siegel and Crozier 2019, 2020) have collected hundreds of papers documenting the major themes relevant for salmon. Here we describe habitat changes relevant to Pacific salmon and steelhead, prior to describing how these changes result in the varied specific mechanisms impacting these species in subsequent sections.

Forests

Climate change will impact forests of the western U.S., which dominate the landscape of many watersheds in the region. Forests are already showing evidence of increased drought severity, forest fire, and insect outbreak (Halofsky et al. 2020). Additionally, climate change will affect tree reproduction, growth, and phenology, which will lead to spatial shifts in vegetation. Halofsky et al. (2018) projected that the largest changes will occur at low- and high-elevation forests, with expansion of low-elevation dry forests and diminishing high-elevation cold forests and subalpine habitats.

Forest fires affect salmon streams by altering sediment load, channel structure, and stream temperature through the removal of canopy. Holden et al. (2018) examined environmental factors contributing to observed increases in the extent of forest fires throughout the western U.S. They found strong correlations between the number of dry-season rainy days and the annual extent of forest fires, as well as a significant decline in the number of dry-season rainy days over the study period (1984-2015). Consequently, predicted decreases in dry-season precipitation, combined with increases in air temperature, will likely contribute to the existing trend toward more extensive and severe forest fires and the continued expansion of fires into higher elevation and wetter forests (Alizedeh 2021).

Agne et al. (2018) reviewed literature on insect outbreaks and other pathogens affecting coastal Douglas-fir forests in the Pacific Northwest and examined how future climate change may influence disturbance ecology. They suggest that Douglas-fir beetle and black stain root disease could become more prevalent with climate change, while other pathogens will be more affected by management practices. Agne et al. (2018) also suggested that due to complex interacting effects of disturbance and disease, climate impacts will differ by region and forest type.

Freshwater Environments
The following is excerpted from Siegel and Crozier (2019), who present a review of recent scientific literature evaluating effects of climate change, describing the projected impacts of climate change on instream flows:

Cooper et al. (2018) examined whether the magnitude of low river flows in the western U.S., which generally occur in September or October, are driven more by summer conditions or the prior winter's precipitation. They found that while low flows were more sensitive to summer evaporative demand than to winter precipitation, interannual variability in winter precipitation was greater. Malek et al. (2018), predicted that summer evapotranspiration is likely to increase in conjunction with declines in snowpack and increased variability in winter precipitation. Their results suggest that low summer flows are likely to become lower, more variable, and less predictable.

The effect of climate change on ground water availability is likely to be uneven. Sridhar et al. (2018) coupled a surface-flow model with a ground-flow model to improve predictions of surface water availability with climate change in the Snake River Basin. Projections using RCP 4.5 and 8.5 emission scenarios suggested an increase in water table heights in downstream areas of the basin and a decrease in upstream areas.

As cited in Siegel and Crozier (2019), Isaak et al. (2018), examined recent trends in stream temperature across the Western U.S. using a large regional dataset. Stream warming trends paralleled changes in air temperature and were pervasive during the low-water warm seasons of 1996-2015 (0.18-0.35°C/decade) and 1976-2015 (0.14-0.27°C/decade). Their results show how continued warming will likely affect the cumulative temperature exposure of migrating sockeye salmon *O. nerka* and the availability of suitable habitat for brown trout *Salmo trutta* and rainbow trout *O. mykiss*. Isaak et al. (2018) concluded that most stream habitats will likely remain suitable for salmonids in the near future, with some becoming too warm. However, in cases where habitat access is currently restricted by dams and other barriers salmon and steelhead will be confined to downstream reaches typically most at risk of rising temperatures unless passage is restored (FitzGerald et al. 2020, Myers et al. 2018).

Streams with intact riparian corridors and that lie in mountainous terrain are likely to be more resilient to changes in air temperature. These areas may provide refuge from climate change for a number of species, including Pacific salmon. Krosby et al. (2018), identified potential stream refugia throughout the Pacific Northwest based on a suite of features thought to reflect the ability of streams to serve as such refuges. Analyzed features include large temperature gradients, high canopy cover, large relative stream width, low exposure to solar radiation, and low levels of human modification. They created an index of refuge potential for all streams in the region, with mountain area streams scoring highest. Flat lowland areas, which commonly contain migration corridors, were generally scored lowest, and thus were prioritized for conservation and restoration. However, forest fires can increase stream temperatures dramatically in short time-spans by removing riparian cover (Koontz et al. 2018), and streams that lose their snowpack with climate change may see the largest increases in stream temperature due to the removal of temperature buffering (Yan et al. 2021). These processes may threaten some habitats that are currently considered refugia.

Marine and Estuarine Environments
Along with warming stream temperatures and concerns about sufficient groundwater to recharge streams, a recent study projects nearly complete loss of existing tidal wetlands along the U.S. West Coast, due to sea level rise (Thorne et al. 2018). California and Oregon showed the greatest threat to tidal wetlands (100%), while 68% of Washington tidal wetlands are expected to be submerged. Coastal development and steep topography prevent horizontal migration of most wetlands, causing the net contraction of this crucial habitat.

Rising ocean temperatures, stratification, ocean acidity, hypoxia, algal toxins, and other oceanographic processes will alter the composition and abundance of a vast array of oceanic species. In particular, there will be dramatic changes in both predators and prey of Pacific salmon, salmon life history traits and relative abundance. Siegel and Crozier (2019) observe that changes in marine temperature are likely to have a number of physiological consequences on fishes themselves. For example, in a study of small planktivorous fish, Gliwicz et al. (2018) found that higher ambient temperatures increased the distance at which fish reacted to prey. Numerous fish species (including many tuna and sharks) demonstrate regional endothermy, which in many cases augments eyesight by warming the retinas. However, Gliwicz et al. (2018) suggest that ambient temperatures can have a similar effect on fish that do not demonstrate this trait. Climate change is likely to reduce the availability of biologically essential omega-3 fatty acids produced by phytoplankton in marine ecosystems. Loss of these lipids may induce cascading trophic effects, with distinct impacts on different species depending on compensatory mechanisms (Gourtay et al. 2018). Reproduction rates of many marine fish species are also likely to be altered with temperature (Veilleux et al. 2018). The ecological consequences of these effects and their interactions add complexity to predictions of climate change impacts in marine ecosystems.

Perhaps the most dramatic change in physical ocean conditions will occur through ocean acidification and deoxygenation. It is unclear how sensitive salmon and steelhead might be to the direct effects of ocean acidification because of their tolerance of a wide pH range in freshwater (although see Ou et al. 2015 and Williams et al. 2019), however, impacts of ocean acidification and hypoxia on sensitive species (e.g., plankton, crabs, rockfish, groundfish) will likely affect salmon indirectly through their interactions as predators and prey. Similarly, increasing frequency and duration of harmful algal blooms may affect salmon directly, depending on the toxin (e.g., saxitoxin vs domoic acid), but will also affect their predators (seabirds and mammals). The full effects of these ecosystem dynamics are not known but will be complex. Within the historical range of climate variability, less suitable conditions for salmonids (e.g., warmer temperatures, lower streamflows) have been associated with detectable declines in many of these listed units, highlighting how sensitive they are to climate drivers (Ford 2022, Lindley et al. 2009, Williams et al. 2016, Ward et al. 2015). In some cases, the combined and potentially additive effects of poorer climate conditions for fish and intense anthropogenic impacts caused the population declines that led to these population groups being listed under the ESA (Crozier et al. 2019).

Climate Change Effects on Salmon and Steelhead
In freshwater, year-round increases in stream temperature and changes in flow will affect physiological, behavioral, and demographic processes in salmon, and change the species with which they interact. For example, as stream temperatures increase, many native salmonids face increased competition with more warm-water tolerant invasive species. Changing freshwater temperatures are likely to affect incubation and emergence timing for eggs, and in locations where the greatest warming occurs may affect egg survival, although several factors impact intergravel temperature and oxygen (e.g., groundwater influence) as well as sensitivity of eggs to thermal stress (Crozier et al. 2020). Changes in temperature and flow regimes may alter the amount of habitat and food available for juvenile rearing, and this in turn could lead to a restriction in the distribution of juveniles, further decreasing productivity through density dependence. For migrating adults, predicted changes in freshwater flows and temperatures will likely increase exposure to stressful temperatures for many salmon and steelhead populations, and alter migration travel times and increase thermal stress accumulation for ESUs or DPSs with early-returning (i.e. spring- and summer-run) phenotypes associated with longer freshwater holding times (Crozier et al. 2020, FitzGerald et al. 2020). Rising river temperatures increase the energetic cost of migration and the risk of en route or pre-spawning mortality of adults with long freshwater migrations, although populations of some ESA-listed salmon and steelhead may be able to make use of cool-water refuges and run-timing plasticity to reduce thermal exposure (Keefer et al. 2018, Barnett et al. 2020).

Marine survival of salmonids is affected by a complex array of factors including prey abundance, predator interactions, the physical condition of salmon within the marine environment, and carryover effects from the freshwater experience (Holsman et al. 2012, Burke et al. 2013). It is generally accepted that salmon marine survival is size-dependent, and thus larger and faster growing fish are more likely to survive (Gosselin et al. 2021). Furthermore, early arrival timing in the marine environment is generally considered advantageous for populations migrating through the CR. However, the optimal day of arrival varies across years, depending on the seasonal development of productivity in the California Current, which affects prey available to salmon and the risk of predation (Chasco et al. 2017). Siegel and Crozier (2019) point out the concern that for some salmon populations, climate change may drive mismatches between juvenile arrival timing and prey availability in the marine environment. However, phenological diversity can contribute to metapopulation-level resilience by reducing the risk of a complete mismatch. Carr-Harris et al. (2018), explored phenological diversity of marine migration timing in relation to zooplankton prey for sockeye salmon *O. nerka* from the Skeena River of Canada. They found that sockeye migrated over a period of more than 50 days, and populations from higher elevation and further inland streams arrived in the estuary later, with different populations encountering distinct prey fields. Carr-Harris et al. (2018) recommended that managers maintain and augment such life-history diversity.

Synchrony between terrestrial and marine environmental conditions (e.g., coastal upwelling, precipitation and river discharge) has increased in spatial scale causing the highest levels of synchrony in the last 250 years (Black et al. 2018). A more synchronized climate combined with simplified habitats and reduced genetic diversity may be leading to more synchrony in the productivity of populations across the range of salmon (Braun et al. 2016). For example, salmon productivity (recruits/spawner) has also become more synchronized across Chinook populations from Oregon to the Yukon (Dorner et al. 2018, Kilduff et al. 2014). In addition, Chinook salmon have become smaller and younger at maturation across their range (Ohlberger et al. 2018). Other Pacific salmon species (Stachura et al. 2014) and Atlantic salmon (Olmos et al. 2020) also have demonstrated synchrony in productivity across a broad latitudinal range.

At the individual scale, climate impacts on salmon in one life stage generally affect body size or timing in the next life stage and negative impacts can accumulate across multiple life stages (Healey 2011; Wainwright and Weitkamp 2013, Gosselin et al. 2021). Changes in winter precipitation will likely affect incubation and/or rearing stages of most populations. Changes in the intensity of cool season precipitation, snow accumulation, and runoff could influence migration cues for fall, winter and spring adult migrants, such as coho and steelhead. Egg survival rates may suffer from more intense flooding that scours or buries redds. Changes in hydrological regime, such as a shift from mostly snow to more rain, could drive changes in life history, potentially threatening diversity within an ESU (Beechie et al. 2006). Changes in summer temperature and flow will affect both juvenile and adult stages in some populations, especially those with yearling life histories and summer migration patterns (Crozier and Zabel 2006; Crozier et al. 2010, Crozier et al. 2019).

At the population level, the ability of organisms to genetically adapt to climate change depends on how much genetic variation currently exists within salmon populations, as well as how selection on multiple traits interact, and whether those traits are linked genetically. While genetic diversity may help populations respond to climate change, the remaining genetic diversity of many populations is highly reduced compared to historic levels. For example, Johnson et al. (2018), compared genetic variation in Chinook salmon from the Columbia River Basin between contemporary and ancient samples. A total of 84 samples determined to be Chinook salmon were collected from vertebrae found in ancient middens and compared to 379 contemporary samples. Results suggest a decline in genetic diversity, as demonstrated by a loss of mitochondrial haplotypes as well as reductions in haplotype and nucleotide diversity. Genetic losses in this comparison appeared larger for Chinook from the mid-Columbia than those from the Snake River Basin. In addition to other stressors, modified habitats and flow regimes may create unnatural selection pressures that reduce the diversity of functional behaviors (Sturrock et al. 2020). Managing to conserve and augment existing genetic diversity may be increasingly important with more extreme environmental change (Anderson et al. 2015), though the low levels of remaining diversity present challenges to this effort (Freshwater 2019). Salmon historically maintained relatively consistent returns across variation in annual weather through the portfolio effect (Schindler et al. 2015), in which different populations are sensitive to different climate drivers. Applying this concept to climate change, Anderson et al (2015) emphasized the additional need for populations with different physiological tolerances. Loss of the portfolio increases volatility in fisheries, as well as ecological systems, as demonstrated for Fraser River and Sacramento River stock complexes (Freshwater et al. 2019, Munsch et al. 2022)

The most recent (2021) biological viability assessment update from Pacific salmon and steelhead has not yet been finalized, but the draft document provides similar findings. It concludes that all PS Chinook salmon populations continue to remain well below the Technical Recovery Team (TRT) planning ranges for recovery escapement levels, and the most populations, including the Cedar and Green River populations, remain consistently below the spawner-recruitment levels identified by the TRT as necessary for recovery. However, it also finds that most populations have increased somewhat in abundance since the last status review in 2016, but still have small negative trends over the past 15 years, with productivity remaining low in most populations.

2.2.1. Status of the Species

For Pacific salmon, steelhead, and certain other species, we commonly used the four "viable salmonid population" (VSP) criteria (McElhany et al. 2000) to assess the viability of the populations that, together, constitute the species. The four criteria (spatial structure, diversity, abundance, and productivity) encompass the species' "reproduction, numbers, or distribution" as described in 50 CFR 402.02. When these parameters are collectively at appropriate levels, they maintain a population's capacity to adapt to various environmental conditions and allow it to sustain itself in the natural environment.

"Spatial structure" refers both to the spatial distributions of individuals in the population and the processes that generate that distribution. A population's spatial structure depends on habitat quality and spatial configuration, and the dynamics and dispersal characteristics of individuals in the population.

"Diversity" refers to the distribution of traits within and among populations. These range in scale from DNA sequence variation in single genes to complex life history traits (McElhany et al. 2000).

"Abundance" generally refers to the number of naturally produced adults (i.e., the progeny of naturally spawning parents) in the natural environment (e.g., on spawning grounds).

"Productivity," as applied to viable factors, refers to the entire life cycle (i.e., the number of naturally-spawning adults produced per parent). When progeny replace or exceed the number of parents, a population is stable or increasing. When progeny fails to replace the number of parents, the population is declining. McElhany et al. (2000) use the terms "population growth rate" and "productivity" interchangeably when referring to production over the entire life cycle. They also refer to "trend in abundance," which is the manifestation of long-term population growth rate.

For species with multiple populations, once the biological status of a species' populations has been determined, we assess the status of the entire species using criteria for groups of populations, as described in recovery plans and guidance documents from technical recovery teams. Considerations for species viability include having multiple populations that are viable, ensuring that populations with unique life histories and phenotypes are viable, and that some viable populations are both widespread to avoid concurrent extinction from mass catastrophes and spatially close to allow functioning as metapopulations (McElhany et al. 2000).

On October 4, 2019, NMFS published notice of NMFS' intent to initiate a new 5-year status review for 28 listed species of Pacific salmon and steelhead and requested updated information from the public to inform the status review (84 FR 53117). On March 24, 2020, NMFS extended the public comment period, from the original March 27, 2020, through May 26, 2020 (85 FR 16619). The Northwest Fishery Science Center (NWFSC) completed the Viability Risk Assessment for salmon and steelhead (Ford 2022). NMFS' West coast Regional Office (WCRO) is currently preparing the final 5-year status review documents, with anticipated completion in 2024. In the section, where possible, particularly as new material becomes available, the latest final (2016) status review information is supplemented with more recent information and other population specific data that may not have been available during the 2016 status review, including some of the information in the draft 2024 status review, so that NMFS is assured of using the best available information for this opinion.

Table 1, below, provides a summary of listing and recovery plan information, status summaries and limiting factors for the species addressed in this opinion. More information can be found in recovery plans and status reviews for these species. Abbreviations appearing in the table include DPS (Distinct Population Segment), ESU (Evolutionarily Significant Unit), ICTRT (Interior Columbia Technical Recovery Team), MPG (Multiple Population Grouping), NWFSC (Northwest Fisheries Science Center), TRT (Technical Recovery Team), and VSP (Viable Salmonid Population).

Table 1. Listing classification and date, recovery plan reference, most recent status review, status summary, and limiting factors for each species considered in this opinion.

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Lower Columbia River Chinook salmon	Threatened 6/28/05	NMFS 2013	NMFS 2022a; Ford 2022	This ESU comprises 32 independent populations. Relative to baseline VSP levels identified in the recovery plan (Dornbusch 2013), there has been an overall improvement in the status of a number of fall-run populations although most are still far from the recovery plan goals; Spring-run Chinook salmon populations in this ESU are generally unchanged; most of the populations are at a "high" or "very high" risk due to low abundances and the high proportion of hatchery-origin fish spawning naturally. Many of the populations in this ESU remain at "high risk," with low natural-origin abundance levels. Overall, we conclude that the viability of the Lower Columbia River Chinook salmon ESU has increased somewhat since 2016, although the ESU remains at "moderate" risk of extinction	• Reduced access to spawning and rearing habitat • Hatchery-related effects • Harvest-related effects on fall Chinook salmon • An altered flow regime and Columbia River plume • Reduced access to off-channel rearing habitat • Reduced productivity resulting from sediment and nutrient-related changes in the estuary • Contaminant
Upper Columbia River spring-run Chinook salmon	Endangered 6/28/05	Upper Columbia Salmon Recovery Board 2007	NMFS 2022b; Ford 2022	This ESU comprises four independent populations. Current estimates of natural-origin spawner abundance decreased substantially relative to the levels observed in the prior review for all three extant populations. Productivities also continued to be very low, and both abundance and productivity remained well below the viable thresholds called for in the Upper Columbia Salmon Recovery Plan for all three populations. Based on the information available for this review, the Upper Columbia River spring-run Chinook salmon ESU remains at high risk, with viability largely unchanged since 2016.	• Effects related to hydropower system in the mainstem Columbia River • Degraded freshwater habitat • Degraded estuarine and nearshore marine habitat • Hatchery-related effects • Persistence of non-native (exotic) fish species • Harvest in Columbia River fisheries

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Snake River spring/summer-run Chinook salmon	Threatened 6/28/05	NMFS 2017a	NMFS 2022c; Ford 2022	This ESU comprises 28 extant and four extirpated populations. There have been improvements in abundance/productivity in several populations relative to the time of listing, but the majority of populations experienced sharp declines in abundance in the recent five-year period Overall, at this time we conclude that the Snake River spring/ summer-run Chinook salmon ESU continues to be at moderate-to-high risk.	• Degraded freshwater habitat • Effects related to the hydropower system in the mainstem Columbia River, • Altered flows and degraded water quality • Harvest-related effects • Predation
Upper Willamette River Chinook salmon	Threatened 6/28/05	NMFS 2011a	NMFS 2024; Ford 2022	This ESU comprises seven populations. Abundance levels for all but Clackamas River DIP remain well below their recovery goals. Overall, there has likely been a declining trend in the viability of the Upper Willamette River Chinook salmon ESU since the last review. The magnitude of this change is not sufficient to suggest a change in risk category, however, so the Upper Willamette River Chinook salmon ESU remains at "moderate" risk of extinction.	• Degraded freshwater habitat • Degraded water quality • Increased disease incidence • Altered stream flows • Reduced access to spawning and rearing habitats • Altered food web due to reduced inputs of microdetritus • Predation by native and non-native species, including hatchery fish • Competition related to introduced salmon and steelhead • Altered population traits due to fisheries and bycatch
Snake River fall-run Chinook salmon	Threatened 6/28/05	NMFS 2017b	NMFS 2022d; Ford 2022	This ESU has one extant population The single extant population in the ESU is currently meeting the criteria for a rating of "viable" developed by the ICTRT, but the ESU as a whole is not meeting the recovery goals described in the recovery plan for the species, which require the single population to be "highly viable with high certainty" and/or will require reintroduction of a viable population above the Hells Canyon Complex (NMFS 2017b). The Snake River fall-run Chinook salmon ESU therefore is considered to be at a moderate-to-low risk of extinction.	• Degraded floodplain connectivity and function • Harvest-related effects • Loss of access to historical habitat above Hells Canyon and other Snake River dams • Impacts from mainstem Columbia River and Snake River hydropower systems • Hatchery-related effects • Degraded estuarine and nearshore habitat.

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Columbia River chum salmon	Threatened 6/28/05	NMFS 2013	NMFS 2022a; Ford 2022	This species has 17 populations divided into 3 MPGs. 3 populations exceed the recovery goals established in the recovery plan (Dornbusch 2013). The remaining populations have unknown abundances. Abundances for these populations are assumed to be at or near zero. The viability of this ESU is relatively unchanged since the last review (moderate to high risk), and the improvements in some populations do not warrant a change in risk category, especially given the uncertainty regarding climatic effects in the near future.	• Degraded estuarine and nearshore marine habitat • Degraded freshwater habitat • Degraded stream flow as a result of hydropower and water supply operations • Reduced water quality • Current or potential predation • An altered flow regime and Columbia River plume • Reduced access to off-channel rearing habitat in the lower Columbia River • Reduced productivity resulting from sediment and nutrient-related changes in the estuary • Juvenile fish wake strandings • Contaminants
Lower Columbia River coho salmon	Threatened 6/28/05	NMFS 2013	NMFS 2022a; Ford 2022	Of the 24 populations that make up this ESU. Only six of the 23 populations for which we have data appear to be above their recovery goals. Overall abundance trends for the Lower Columbia River coho salmon ESU are generally negative. Natural spawner and total abundances have decreased in almost all DIPs, and Coastal and Gorge MPG populations are all at low levels, with significant numbers of hatchery-origin coho salmon on the spawning grounds. Improvements in spatial structure and diversity have been slight, and overshadowed by declines in abundance and productivity. For individual populations, the risk of extinction spans the full range, from “low” to “very high.” Overall, the Lower Columbia River coho salmon ESU remains at “moderate” risk, and viability is largely unchanged since 2016.	• Degraded estuarine and near-shore marine habitat • Fish passage barriers • Degraded freshwater habitat: Hatchery-related effects • Harvest-related effects • An altered flow regime and Columbia River plume • Reduced access to off-channel rearing habitat in the lower Columbia River • Reduced productivity resulting from sediment and nutrient-related changes in the estuary • Juvenile fish wake strandings • Contaminants

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Snake River sockeye salmon	Endangered 6/28/05	NMFS 2015	NMFS 2022e; Ford 2022	This single population ESU is at remains at “extremely high risk,” although there has been substantial progress on the first phase of the proposed recovery approach—developing a hatchery-based program to amplify and conserve the stock to facilitate reintroductions. Current climate change modeling supports the “extremely high risk” rating with the potential for extirpation in the near future (Crozier et al. 2020). The viability of the Snake River sockeye salmon ESU therefore has likely declined since the time of the prior review, and the extinction risk category remains “high.”	• Effects related to the hydropower system in the mainstem Columbia River • Reduced water quality and elevated temperatures in the Salmon River • Water quantity • Predation
Upper Columbia River steelhead	Threatened 1/5/06	Upper Columbia Salmon Recovery Board 2007	NMFS 2022b; Ford 2022	This DPS comprises four independent populations. The most recent estimates (five-year geometric mean) of total and natural-origin spawner abundance have declined since the last report, largely erasing gains observed over the past two decades for all four populations (Figure 12, Table 6). Recent declines are persistent and large enough to result in small, but negative 15-year trends in abundance for all four populations. The overall Upper Columbia River steelhead DPS viability remains largely unchanged from the prior review, and the DPS is at high risk driven by low abundance and productivity relative to viability objectives and diversity concerns.	• Adverse effects related to the mainstem Columbia River hydropower system • Impaired tributary fish passage • Degraded floodplain connectivity and function, channel structure and complexity, riparian areas, large woody debris recruitment, stream flow, and water quality • Hatchery-related effects • Predation and competition • Harvest-related effects

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Lower Columbia River steelhead	Threatened 1/5/06	NMFS 2013	NMFS 2022a; Ford 2022	This DPS comprises 23 historical populations, 17 winter-run populations and 6 summer-run populations. 10 are nominally at or above the goals set in the recovery plan (Dornbusch 2013); however, it should be noted that many of these abundance estimates do not distinguish between natural- and hatchery- origin spawners. The majority of winter-run steelhead DIPs in this DPS continue to persist at low abundance levels (hundreds of fish), with the exception of the Clackamas and Sandy River DIPs, which have abundances in the low 1,000s. Although the five-year geometric abundance means are near recovery plan goals for many populations, the recent trends are negative. Overall, the Lower Columbia River steelhead DPS is therefore considered to be at "moderate" risk.,	• Degraded estuarine and nearshore marine habitat • Degraded freshwater habitat • Reduced access to spawning and rearing habitat • Avian and marine mammal predation • Hatchery-related effects • An altered flow regime and Columbia River plume • Reduced access to off-channel rearing habitat in the lower Columbia River • Reduced productivity resulting from sediment and nutrient-related changes in the estuary • Juvenile fish wake strandings • Contaminants
Upper Willamette River steelhead	Threatened 1/5/06	NMFS 2011a	NMFS 2024; Ford 2022	This DPS has four demographically independent populations. Populations in this DPS have experienced long-term declines in spawner abundance. Although the recent magnitude of these declines is relatively moderate, continued declines would be a cause for concern. In the absence of substantial changes in accessibility to high-quality habitat, the DPS will remain at "moderate-to-high" risk. Overall, the Upper Willamette River steelhead DPS is therefore at "moderate-to-high" risk, with a declining viability trend.	• Degraded freshwater habitat • Degraded water quality • Increased disease incidence • Altered stream flows • Reduced access to spawning and rearing habitats due to impaired passage at dams • Altered food web due to changes in inputs of microdetritus • Predation by native and non-native species, including hatchery fish and pinnipeds • Competition related to introduced salmon and steelhead • Altered population traits due to interbreeding with hatchery origin fish

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
Middle Columbia River steelhead	Threatened 1/5/06	NMFS 2009	NMFS 2022f; Ford 2022	This DPS comprises 17 extant populations. Recent (five-year) returns are declining across all populations, the declines are from relatively high returns in the previous five-to-ten year interval, so the longer-term risk metrics that are meant to buffer against short-period changes in abundance and productivity remain unchanged. The Middle Columbia River steelhead DPS does not currently meet the viability criteria described in the Middle Columbia River steelhead recovery plan.	• Degraded freshwater habitat • Mainstem Columbia River hydropower-related impacts • Degraded estuarine and nearshore marine habitat • Hatchery-related effects • Harvest-related effects • Effects of predation, competition, and disease
Snake River basin steelhead	Threatened 1/5/06	NMFS 2017a	NMFS 2022g; Ford 2022	This DPS comprises 24 populations. Based on the updated viability information available for this review, all five MPGs are not meeting the specific objectives in the draft recovery plan, and the viability of many individual populations remains uncertain. Of particular note, the updated, population-level abundance estimates have made very clear the recent (last five years) sharp declines that are extremely worrisome, were they to continue.	• Adverse effects related to the mainstem Columbia River hydropower system • Impaired tributary fish passage • Degraded freshwater habitat • Increased water temperature • Harvest-related effects, particularly for B-run steelhead • Predation • Genetic diversity effects from out-of-population hatchery releases
Southern DPS of eulachon	Threatened 3/18/10	NMFS 2017c	NMFS 2022h	The Southern DPS of eulachon includes all naturally-spawned populations that occur in rivers south of the Nass River in British Columbia to the Mad River in California. Sub populations for this species include the Fraser River, Columbia River, British Columbia and the Klamath River. In the early 1990s, there was an abrupt decline in the abundance of eulachon returning to the Columbia River. Despite a brief period of improved returns in 2001-2003, the returns and associated commercial landings eventually declined to the low levels observed in the mid-1990s. Although eulachon abundance in monitored rivers has generally improved, especially in the 2013-2015 return years, recent poor ocean conditions and the likelihood that these conditions will persist into the near future suggest that population declines may be widespread in the upcoming return years.	• Changes in ocean conditions due to climate change, particularly in the southern portion of the species' range where ocean warming trends may be the most pronounced and may alter prey, spawning, and rearing success. • Climate-induced change to freshwater habitats • Bycatch of eulachon in commercial fisheries • Adverse effects related to dams and water diversions • Water quality, • Shoreline construction • Over harvest • Predation

2.2.2 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).

For most salmon and steelhead, NMFS's critical habitat analytical review teams (CHARTs) ranked watersheds within designated critical habitat at the scale of the fifth-field hydrologic unit code (HUC5) in terms of the conservation value they provide to each ESA-listed species that they support (NMFS 2005). The conservation rankings were high, medium, or low. To determine the conservation value of each watershed to species viability, the CHARTs evaluated the quantity and quality of habitat features, the relationship of the area compared to other areas within the species' range, and the significance to the species of the population occupying that area. Even if a location had poor habitat quality, it could be ranked with a high conservation value if it were essential due to factors such as limited availability, a unique contribution of the population it served, or is serving another important role.

For southern DPS eulachon, critical habitat includes portions of 16 rivers and streams in California, Oregon, and Washington (USDC 2011). We designated all of these areas as migration and spawning habitat for this species.

A summary of the status of critical habitats considered in this opinion is provided in Table 2, below.

Table 2. Critical habitat, designation date, federal register citation, and status summary for critical habitat considered in this opinion.

Species	Designation Date and Federal Register Citation	Critical Habitat Status Summary
Lower Columbia River Chinook salmon	9/02/05 70 FR 52630	Critical habitat encompasses 10 subbasins in Oregon and Washington containing 47 occupied watersheds, as well as the lower Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some, or high potential for improvement. We rated conservation value of HUC5 watersheds as high for 30 watersheds, medium for 13 watersheds, and low for four watersheds.
Upper Columbia River spring-run Chinook salmon	9/02/05 70 FR 52630	Critical habitat encompasses four subbasins in Washington containing 15 occupied watersheds, as well as the Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition. However, most of these watersheds have some, or high, potential for improvement. We rated conservation value of HUC5 watersheds as high for 10 watersheds, and medium for five watersheds. Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.
Snake River spring/summer-run Chinook salmon	10/25/99 64 FR 57399	Critical habitat consists of river reaches of the Columbia, Snake, and Salmon rivers, and all tributaries of the Snake and Salmon rivers (except the Clearwater River) presently or historically accessible to this ESU (except reaches above impassable natural falls and Hells Canyon Dam). Habitat quality in tributary streams varies from excellent in wilderness and roadless areas, to poor in areas subject to heavy agricultural and urban development (Wissmar et al. 1994). Reduced summer stream flows, impaired water quality, and reduced habitat complexity are common problems. Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.
Upper Willamette River Chinook salmon	9/02/05 70 FR 52630	Critical habitat encompasses 10 subbasins in Oregon containing 56 occupied watersheds, as well as the lower Willamette/Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition. However, most of these watersheds have some, or high, potential for improvement. Watersheds are in good to excellent condition with no potential for improvement only in the upper McKenzie River and its tributaries (NMFS 2005). We rated conservation value of HUC5 watersheds as high for 22 watersheds, medium for 16 watersheds, and low for 18 watersheds.
Snake River fall-run Chinook salmon	10/25/99 64 FR 57399	Critical habitat consists of river reaches of the Columbia, Snake, and Salmon rivers, and all tributaries of the Snake and Salmon rivers presently or historically accessible to this ESU (except reaches above impassable natural falls, and Dworshak and Hells Canyon dams). Habitat quality in tributary streams varies from excellent in wilderness and roadless areas, to poor in areas subject to heavy agricultural and urban development (Wissmar et al. 1994). Reduced summer stream flows, impaired water quality, and reduced habitat complexity are common problems. Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.

Species	Designation Date and Federal Register Citation	Critical Habitat Status Summary
Columbia River chum salmon	9/02/05 70 FR 52630	Critical habitat encompasses six subbasins in Oregon and Washington containing 19 occupied watersheds, as well as the lower Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of HUC5 watersheds as high for 16 watersheds, and medium for three watersheds.
Lower Columbia River coho salmon	2/24/16 81 FR 9252	Critical habitat encompasses 10 subbasins in Oregon and Washington containing 55 occupied watersheds, as well as the lower Columbia River and estuary rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of HUC5 watersheds as high for 34 watersheds, medium for 18 watersheds, and low for three watersheds.
Snake River sockeye salmon	10/25/99 64 FR 57399	Critical habitat consists of river reaches of the Columbia, Snake, and Salmon rivers; Alturas Lake Creek; Valley Creek; and Stanley, Redfish, Yellow Belly, Pettit and Alturas lakes (including their inlet and outlet creeks). Water quality in all five lakes generally is adequate for juvenile sockeye salmon, although zooplankton numbers vary considerably. Some reaches of the Salmon River and tributaries exhibit temporary elevated water temperatures and sediment loads that could restrict sockeye salmon production and survival (NMFS 2015b). Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.
Upper Columbia River steelhead	9/02/05 70 FR 52630	Critical habitat encompasses 10 subbasins in Washington containing 31 occupied watersheds, as well as the Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of HUC5 watersheds as high for 20 watersheds, medium for eight watersheds, and low for three watersheds.
Lower Columbia River steelhead	9/02/05 70 FR 52630	Critical habitat encompasses nine subbasins in Oregon and Washington containing 41 occupied watersheds, as well as the lower Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of HUC5 watersheds as high for 28 watersheds, medium for 11 watersheds, and low for two watersheds.
Upper Willamette River steelhead	9/02/05 70 FR 52630	Critical habitat encompasses seven subbasins in Oregon containing 34 occupied watersheds, as well as the lower Willamette/Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. Watersheds are in good to excellent condition with no potential for improvement only in the upper McKenzie River and its tributaries (NMFS 2005). We rated conservation value of HUC5 watersheds as high for 25 watersheds, medium for 6 watersheds, and low for 3 watersheds.

Species	Designation Date and Federal Register Citation	Critical Habitat Status Summary
Middle Columbia River steelhead	9/02/05 70 FR 52630	Critical habitat encompasses 15 subbasins in Oregon and Washington containing 111 occupied watersheds, as well as the Columbia River rearing/migration corridor. Most HUC5 watersheds with PCEs for salmon are in fair-to-poor or fair-to-good condition (NMFS 2005). However, most of these watersheds have some or a high potential for improvement. We rated conservation value of occupied HUC5 watersheds as high for 80 watersheds, medium for 24 watersheds, and low for 9 watersheds.
Snake River basin steelhead	9/02/05 70 FR 52630	Critical habitat encompasses 25 subbasins in Oregon, Washington, and Idaho. Habitat quality in tributary streams varies from excellent in wilderness and roadless areas, to poor in areas subject to heavy agricultural and urban development (Wissmar et al. 1994). Reduced summer stream flows, impaired water quality, and reduced habitat complexity are common problems. Migratory habitat quality in this area has been severely affected by the development and operation of the dams and reservoirs of the Federal Columbia River Power System.
Southern DPS of eulachon	10/20/11 76 FR 65324	Critical habitat for eulachon includes portions of 16 rivers and streams in California, Oregon, and Washington. All of these areas are designated as migration and spawning habitat for this species. In Oregon, we designated 24.2 miles of the lower Umpqua River, 12.4 miles of the lower Sandy River, and 0.2 miles of Tenmile Creek. We also designated the mainstem Columbia River from the mouth to the base of Bonneville Dam, a distance of 143.2 miles. Dams and water diversions are moderate threats to eulachon in the Columbia and Klamath rivers where hydropower generation and flood control are major activities. Degraded water quality is common in some areas occupied by southern DPS eulachon. In the Columbia and Klamath river basins, large-scale impoundment of water has increased winter water temperatures, potentially altering the water temperature during eulachon spawning periods. Numerous chemical contaminants are also present in spawning rivers, but the exact effect these compounds have on spawning and egg development is unknown. Dredging is a low to moderate threat to eulachon in the Columbia River. Dredging during eulachon spawning would be particularly detrimental.

2.3. Action Area

"Action area" means all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). The action areas for this consultation include four areas around each project location (Figures 1 and 2). The four areas are delineated by the greatest extent of physical, chemical and biological effects of the proposed action. Each project has a distinct action area. Each project's action area is inclusive of areas where modified habitat conditions – including overwater surface coverage and downstream extent of turbidity during spud pile removal and installation – are likely to occur.

Both projects will generate airborne noise and involve in-water work, so the action area is composed of both in-water and airborne areas of zones of potential effects. The Action Area will include a terrestrial zone of effect related to the construction noise extending in all directions from the project areas for 100 feet. The aquatic portion of the Action Area includes areas of potential turbidity increases, estimated to extend downstream no more than 200 feet (temporary mixing zone) from each project's perimeter.

2.4. Environmental Baseline

The "environmental baseline" refers to the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action. The environmental baseline includes the past and present impacts of all federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed federal projects in the action area that have already undergone formal or early section 7 consultations, and the impact of State or private actions which are contemporaneous with the consultation in process. The impacts to listed species or designated critical habitat from federal agency activities or existing federal agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 CFR 402.02).

The applicant describes the environmental baseline of critical habitats in the Environmental Setting section in its biological assessment for Barge 30 (ELS 2023 at pp. 1-2) and its Proponent and Location and Project Description sections in its biological assessment for Barge 513 (ELS 2024 at pp. 1-2). In summary, they describe the environmental baseline as degraded due to previous and ongoing human activities including hydropower, industrialization, and urbanization and associated consequences such as habitat loss, habitat fragmentation, and chemical contamination.

The action area is within critical habitat for numerous listed salmon and steelhead. Critical habitat includes PBFs necessary to support various life stages of salmonid and non-salmonid listed species (i.e., rearing, migration). NMFS reviews effects on critical habitat affected by a proposed action by examining how the PBFs of critical habitat would be altered, and the duration of such changes. For Snake River listed salmonids, PBFs of designated critical habitat in the action area contains juvenile rearing and juvenile/adult migration corridor habitat components. While the action area is small proportional to the suite of critical habitat areas providing these PBFs, it is important as it is part of a migratory corridor through which all upstream migrating adults and downstream migrating juveniles must pass.

The baseline also includes the effects of projects that have proceeded subsequent to section 7 consultation. During the last several years, NMFS has engaged in multiple section 7 consultations on Federal projects adversely affecting ESA-listed fish and their habitats in or near the action area. These include vicinity (Multnomah County, Oregon; Clark County, Washington) adjacent to or within the action area (WCRO-2022-01443, WCRO-2020-03117, WCRO-2020-01523, WCRO-2020-03569, WCR-2019-11648, WCR-2018-10138, WCR-2017-7450, WCR-2017-6622, WCR-2016-5136), including the effects of actions addressed in programmatic consultations (the SLOPES IV programmatic consultation, NMFS number WCR-2011-00002). In general, those actions caused temporary, construction-related effects (increased noise and turbidity), and longer-term effects like increasing and/or perpetuating overwater coverage.

2.5. Effects of the Action

Under the ESA, "effects of the action" are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action but that are not part of the action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action (see 50 CFR 402.02).

As the action area is in the LCR, many populations of listed salmon and steelhead species will encounter the proposed structures including MCR and UCR species over the lifetime of the structure. Out-migrating juveniles from all upriver populations will be exposed to increased predation risk as they migrate past the structures. Each generation of juveniles will be exposed to these effects over the lifetime of the structures. Some individual populations that spawn in the CR mainstem or its tributaries downstream of the action area (for example, the Cowlitz River population of CR chum salmon, as well as UWR Chinook and steelhead) are unlikely to be exposed to Vancouver Barge 30 Replacement project's (WCRO-2023-03223) effects of the proposed actions. However, all 13 species identified in Table

Temporary effects of the proposed action are reasonably certain to include:

- Localized benthic impacts due to dropping of spuds (e.g., increased turbidity, resuspended contaminants)
- Potential contaminant releases to the river from vessels during replacement/relocation activities

Enduring effects of the proposed action are reasonably certain to include:

- Perpetuation of over-water structure presence of the 4 spud barges (shade, predation)
- Potential contaminant releases including polycyclic aromatic hydrocarbons (PAHs) from moored boats over the lifespan of the structure
- Benthic habitat loss from dropped spuds
- Scour of nearshore areas from prop wash

All populations of the following species will be exposed to enduring effects from both barge replacements: UCR spring run Chinook salmon, SR spring/summer-run Chinook salmon, SR fall-run Chinook salmon, SR sockeye salmon, UCR steelhead, MCR steelhead, and SR steelhead. CR chum salmon, LCR coho salmon, LCR Chinook salmon, and LCR steelhead. Additionally, Barge 513 will affect UWR steelhead and Chinook salmon as described below.

2.5.1. Effects on Critical Habitat

As mentioned in Section 2.2, portions of the action area include designated critical habitat for each of the 13 ESA-listed ESUs/DPSs of salmonids within the LCR and the southern DPS of eulachon. Critical habitat includes PBFs necessary to support various life stages of salmonid and non-salmonid listed species (i.e., rearing, migration). NMFS reviews effects on critical habitat affected by a proposed action by examining how the PBFs of critical habitat would be altered, and the duration of such changes.

Two of the six PBFs established for salmonid critical habitat are likely to be present in the action area. Those PBFs are:

1. Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.

2. Freshwater migration corridors free of obstruction 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. These features are essential to conservation because without them juveniles cannot use the variety of habitats that allow them to avoid high flows, avoid predators, successfully compete, begin the behavioral and physiological changes needed for life in the ocean, and reach the ocean in a timely manner.

Two of the three PBFs established for the southern DPS of eulachon are likely to be present within the action area. Those PBFs are:

1. Freshwater spawning and incubation sites with water flow, quality and temperature conditions and substrate supporting spawning and incubation, and with migratory access for adults and juveniles.

2. Freshwater and estuarine migration corridors associated with spawning and incubation sites that are free of obstruction and with water flow, quality and temperature conditions supporting larval and adult mobility, and with abundant prey items supporting larval feeding after the yolk sac is depleted.

Salmonid Critical Habitat

Shading and Predation

Throughout the action, the gangway(s) and moored vessels may attract juvenile salmonid predators to shallow water areas due to shading they may produce. Juvenile salmonids are usually reluctant to enter shaded zones created by over-water structures, piles (spuds), and moored vessels. These areas create favorable ambush habitat for predators such as smallmouth bass, largemouth bass, and Northern pikeminnow. The overwater shade and the slower stream velocity caused by these structures can be easily exploited by these piscivores. Additionally, migrating smolts that swim near the structures would be more vulnerable to avian predators. These birds may perch on dock structures or moored vessels. Piscivorous birds present in the CR that feed on juvenile salmonids include double-crested cormorants, California and ring-billed gulls, and Caspian terns (Sebring et al. 2013).

After the action, all juvenile salmonids could occur near the structures while migrating downriver, and be vulnerable to fish predators using the piles (spuds) for ambushing migrating juveniles. Adult migration will not be affected by the proposed action because adults will simple avoid the work area. The presence of the structures will adversely affect juvenile salmonids and the safe migration value of designated critical habitat in the action area.

Shading and predation will have a small effect on adult eulachon migration because adult eulachon are large enough to avoid piscine predators and are likely to swim around the structure. Larval eulachon which drift passively to the estuary are likely to be consumed by juvenile piscine predators where they drift under or adjacent to the replacement structures. However, the relatively small area occupied by the physical presence of the structures will limit mortality to a very small portion of the eulachon run. Therefore, shading and predation will have a small affect on designated eulachon critical habitat.

Benthic prey

Shading from the structures and moored vessels also has the potential to impact forage opportunities by perpetuating disturbances to benthic communities. Overwater shade can disrupt the growth of submerged aquatic vegetation (SAV), reducing forage availability for juvenile salmonids and other small fish that comprise the adult salmonid prey base. The proposed action extends the duration of shading impacts on benthic communities; however, it is expected to be relatively minor.

Water Quality

Water quality of the critical habitat in the action area would be temporarily affected by increased TSS during spud removal and installation, and all additional in-water work. Once in the water column, the CR would transport suspended sediments downstream. The sediment at the action area is mainly composed of alluvial sand and silt which would be expected to settle out of the water column quickly (Newcombe & Jensen, 1996). While spud removal and installation and in-water work increase TSS, any impact on rearing and migration PBFs would be localized and temporary. Increased TSS would return to baseline levels as soon as replacement/relocation activities are completed.

Resuspended sediments

Effects to critical habitat from an increase in resuspended contaminants is not expected to be permanent. Migration is unlikely to be appreciably diminished by these sources of water quality reduction, however rearing could be incrementally and chronically diminished by the chemical contaminants reducing prey communities or creating a source for bioaccumulation. Also, growth and fitness values of rearing could be diminished. This effect is discussed in effects on listed species, below.

Benthic Impacts
The installation of spuds will eliminate a small amount of benthic habitat which supports forage for migrating and rearing juvenile salmonids. The reduction of this PBF is small relative to existing conditions.

Similar to effects on benthic prey above, associated commercial and recreational vessel use also adversely affects SAV where it is present, and inhibits its recruitment where not present, by frequently churning water and sediment in the shallow water environment. Additionally, the turbidity from boat propeller wash decreases light levels (Eriksson et al. 2004). Shafer (1999; 2002) provides background information on the light requirements of seagrasses and documents the effects of reduced light availability on seagrass biomass and density, growth, and morphology. Decreased ambient light typically results in lower overall productivity, which is ultimately reflected in lower shoot density and biomass (Shafer 1999; 2002).

Areas where sediment is routinely disturbed by prop wash will also experience repeated disruption of benthic prey communities, suppressing this forage source.

The proposed action perpetuates instances of prop wash effects on benthic communities (flora and fauna); however, it is expected to be relatively minor.

Eulachon Critical Habitat
Increased turbidity will temporarily impair water quality and impair freshwater spawning and incubation habitat in the action area. Although spawning has not been documented within the action area, substrates suitable for egg adhesion may occur in the action area. The proposed action is not expected to obstruct adult eulachon migration through the river or larval downstream drift. The effects described above will only impact areas in proximity to the structures and will be temporary in nature, returning to pre-project levels once replacement/relocation activities cease. However, predation effects will impede the migration corridor for larval eulachon.

2.5.2. Effects on ESA-listed species

Short-term Effects
Water quality impairment
During spud removal and installation and any in-water work, there will be an increase in total suspended solids (TSS) in the action area. Some salmonids may experience temporary effects as a result of these activities during the work window. According to Newcombe and Jensen (1996), the effects of increased TSS on exposed fish can range from beneficial (improved survival by reduced predation) to detrimental (physiological stress and reduced growth). Constant exposure to turbid conditions by fish may cause physiological stress responses that increase an individual's maintenance energy needs, and reduce feeding and growth (Lloyd et al., 1987; Redding et al., 1987; Servizi & Martens, 1991). These responses may include gill flaring, coughing, and a temporary reduced feeding rate. A study by Bisson and Bilby (1982) found that salmonids are able to detect and distinguish turbidity and other water quality gradients.

Larger adult salmon quickly respond to turbidity by avoiding the areas. Other studies show that larger salmonids tolerate elevated TSS when compared to smaller juveniles (Servizi & Martens, 1991, 1992). As salmonids grow and their swimming ability improves, they depend less on shallow, nearshore habitats (Groot & Margolis, 1991). Consequently, we expect any adults exposed to elevated TSS to traverse or swim around the action area without experiencing adverse effects.

Juvenile salmonids exposed to elevated TSS would experience similar physiological responses to adult salmonids (described above). The risk of exposure to turbidity is greater for sub-yearling salmonids than yearling salmonids and adults. Sub-yearling salmonids are known to reside (over-winter) in the lower CR up to a year before emigrating to the ocean (Johnson et al. 2015). However, the temporary duration of the proposed action and CR flow dynamics make the possibility of prolonged exposure to turbid conditions very unlikely. It is possible that behavioral alteration might make juveniles more susceptible to predation as they relocate to other areas. Although a small number of sub-yearling juvenile salmonids may be harmed by increased TSS, we expect effects among the juveniles exposed to be minor and predominantly a behavioral avoidance response.

We anticipate that any eulachon that would arrive within the action area during its undertaking would have a similar response to the turbidity and contaminant effects caused by the proposed action as adult salmonids. Adult eulachon are highly mobile and would likely avoid areas with elevated TSS. Also, adult eulachon would not be harmed by resuspended sediments as they are semelparous and usually die shortly after spawning. We expect turbidity effects to be limited to a few individuals that might be present during the proposed action.

Benthic disturbance

Adult salmonids do not consume benthic invertebrates as a prey base. Adult salmon also usually cease prey consumption during their upstream migration (Quinn, 2018). Consequently, the reduction in invertebrate forage related to benthic disturbance or existing and temporarily increased shade (construction vessel staging) would not have a significant effect on adult ESA-listed species considered in this opinion.

The benthic prey of juvenile salmonids are likely to be diminished due to the elevated TSS caused by the proposed action. Effects on the prey are likely to be minor among juveniles, affecting those, if any, rearing in the action area more than those migrating through the action area. Rearing juveniles with less available prey in the action area are expected to find suitable areas in nearby unaffected areas, but may experience increased competition for those prey resources. Additionally, in-water structures in the action area may provide foraging habitat and may compensate for the loss of some benthic prey. According to Carrasquero (2001), juvenile salmonids may prey on periphyton, insects, and macroinvertebrates that adhere to in-water structures (such as steel piles/spuds) in the CR. Additionally, juveniles present will likely be avoiding the action area due to increased underwater noise and TSS, therefore we expect benthic prey disturbance to have a minor and temporary effect on juvenile salmonids.

We expect that any adult eulachon present in the action area would have a similar response to the benthic effects caused by the proposed action as the salmonids would. Adult eulachon are likely to respond to permanent habitat effects similarly to adult salmonids, by a slight adjustment in their migration pathway.

Enduring Effects
Shading and Predation
Adult salmonids are too large to be consumed by piscivorous fish that may use in-water and over-water structures as ambush habitat in the CR. Adult salmonids tend to travel through the middle of the river channel and in deeper water. Therefore, the adults traversing the CR are least likely to experience adverse benthic disturbance effects. We expect that the few adults that may encounter the structures would swim around and/or underneath the structures with little to no variation in their migration trajectory.

Yearling salmonid juveniles would respond to the structure by swimming around the structure, which would only slightly lengthen their migratory pathway. Such adjustments to their migration route can potentially be an adverse effect. These route alterations may increase individual energy expenditure, increase opportunities for predators to prey on juveniles, and has been shown to be correlated with mortality (Anderson et al., 2015). Rearing sub-yearling juveniles may also experience degraded habitat conditions due to shade. Shade reduces forage opportunities for juveniles and displaces smaller juveniles from shallow water rearing habitat. The barges may create some shade and reduce water velocity that could likely make existing habitat conditions more attractive to predators. Studies found that pikeminnow and smallmouth bass actively search for low-velocity habitats, prefer shaded areas, and utilize overwater structures such as docks (Faler et al., 1988; Isaak & Bjornn, 1996; Martinelli & Shively, 1997). The barge replacements would expand the use of shaded and lower velocity areas preferred by piscivorous fish. Consequently, to the extent the barges will remain in the habitat, they would continue contributing to a reduction in the quality of the migratory corridor and rearing habitat. As a consequence, a few juvenile salmonids, especially sub-yearlings, are likely to be consumed by piscine predators.

Adult eulachon are typically 6–8 inches in length, and are usually beyond the gape limit of all piscivorous fish except for the largest fish found in the LCR. Thus, we do not anticipate this life stage to be subjected to increased predation risk because of the proposed action. However, larval, juvenile, and egg life history forms are likely to be consumed by predators using the barges as ambush cover.

Exposure to noise from boat/vessel traffic
Recreational boat/commercial vessel activity is known to cause physiological stress to fish (Nicholes et al., 2015). However, the effect is only expected intermittently for a few minutes at a time. The fishes that encounter noise would likely move away from the area. Due to the intermittent nature of the disturbance and the ability for fish to move away, we do not expect this effect to be meaningful to the survival of adult or juvenile fish that encounter noise disturbance from boats/vessels.

2.6. Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving federal activities, that are reasonably certain to occur within the action area of the federal action subject to consultation [50 CFR 402.02]. Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Some continuing non-federal activities 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 earlier in the discussion of the rangewide status of the species and the environmental baseline (Sections. 2.2 and 2.4).

Approximately six million people live in the CR basin, concentrated largely in urban centers. The effect of that population is expressed as changes to physical habitat and loadings of pollutants contributed to the CR over time. These changes are caused by residential, commercial, industrial, agricultural, and other land uses for economic development, and are also described in the environmental baseline (Section 2.4). The collective effects of these activities tend to be expressed most strongly in lower river systems where the impacts of numerous upstream land management actions aggregate to influence natural habitat processes and water quality. As human population grows, the range of effects described here are likely to intensify.

Resource-based industries (e.g., agriculture, hydropower facilities, timber harvest, fishing, and metals and gravel mining) caused many long-lasting environmental changes that harmed ESA-listed species and their critical habitats, such as basin-wide loss or degradation of stream channel morphology, spawning substrates, instream roughness and cover, estuarine rearing habitats, wetlands, floodplains, riparian areas, water quality (e.g., temperature, sediment, dissolved oxygen, contaminants), fish passage, and habitat refugia. Those changes reduced the ability of populations of ESA-listed species to sustain themselves in the natural environment by altering or interfering with their behavior in ways that reduce their survival throughout their life cycle. The environmental changes also reduced the quality and function of critical habitat PBFs that are necessary for successful spawning, production of offspring, and migratory access necessary for adult fish to swim upstream to reach spawning areas and for juvenile fish to proceed downstream and reach the ocean. Without those features, the species cannot successfully spawn and produce offspring.

While widespread degradation of aquatic habitat associated with intense natural resource extraction is no longer common, ongoing and future land management actions are likely to continue to have a depressive effect on aquatic habitat quality in the CR basin and within the action area. Additionally, as human population grows, other non-federal uses of the river are likely to increase and intensify, such as recreational boating and fishing, and nonpoint stormwater inputs from upland areas. With increased water-based recreation comes increased frequency of point-source pollution events such as oil and fuel spills, and increased presence of polycyclic aromatic hydrocarbons (PAH) in the aquatic environment. PAHs are long-lasting, have toxic effects on humans and other organisms, and are associated with cancer. In fishes, PAHs are carcinogenic and linked with a diverse suite of negative effects including reproductive, behavioral, and growth problems (Logan 2007). Tire particles contain 6PPD-quinone, which is acutely toxic to juvenile coho and Chinook salmon (Lo et al. 2023). Exposure to this toxin through stormwater runoff is likely to increase with increasing traffic along Washington roads adjacent or with ultimate drainage to the CR. Increased water-based recreation may also be associated with increased fishing pressure and increased risk of invasive species transmission into the action areas and to/from the LCR. Ongoing use of the CR navigation channel and increases in vessel traffic may increase ship wake stranding of juvenile salmonids and eulachon and exacerbate nearshore habitat erosion and degradation. Ongoing maintenance and presence of shoreline armoring has degraded natural shoreline and floodplain function. As a result, recovery of aquatic habitat is likely to be slow in most areas, and contemporaneous cumulative effects from basin-wide activities are likely to have a slightly negative impact on population abundance trends and the quality of critical habitat PBFs into the future.

2.7. Integration and Synthesis

The Integration and Synthesis section is the final step in assessing the risk that the proposed action poses to species and critical habitat. In this section, we add the effects of the action (Section 2.4) to the environmental baseline (Section 2.3) and the cumulative effects (Section 2.5), taking into account the status of the species and critical habitat (Section 2.2), to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated or proposed critical habitat as a whole for the conservation of the species.

2.7.1. Critical Habitat

This project will add to the degraded critical habitat condition. The proposed action will include a brief disruption to water quality, diminishment of rearing and migration value, a very small area of forage reduction, a long-term reduction in safe passage, and a long-term potential diminishment of habitat values from possible contaminant releases. Most of the habitat value reductions will quickly ameliorate to their baseline levels. The disruption to water quality will take place due to sediment releases during spud removal and installation (11 total spuds; the two spuds removed then three installed at Kalama will occur in deep water). The reduced forage will be due to installation of 11 spuds. Three of those spuds, installed at Kalama, will reside in deep water.

The diminished rearing and migration values will be due to: (1) increased predation risk to juveniles due to the perpetual overwater surface coverage of the structures and associated moored vessels; (2) reduced safe passage due to potential contaminant releases from moored vessels. This risk is most pronounced for CR chum salmon and LCR fall Chinook salmon, as these are youngest/smallest outmigrants based on their short freshwater rearing behavior. However, the quantity and quality of these stressors will be a fractional increase within overall effects within the baseline, and NMFS cannot discern a meaningful reduction in the value of the critical habitat PBFs to support juvenile survival, growth, maturation, and development. Climate change impacts are not anticipated to meaningfully interact with critical habitat effects of the proposed action. Thus, the proposed action will not adversely modify critical habitat for any of the species considered in this opinion.

2.7.2. ESA-Listed Species

Of the species and populations that will encounter the proposed structures, a subset will be present and exposed to short-term effects of replacement of structures and subsequent piling removal and installation activities, in addition to long-term effects. All populations that will be exposed to effects of the proposed action are important for species recovery. Each population plays a unique role in the survival and recovery of their respective species as described in the recovery plan for LCR species (NMFS 2013), MCR Steelhead (NMFS 2009), UCR spring Chinook salmon and steelhead (NMFS 2007), SR fall-run Chinook salmon (NMFS 2017), SR spring and summer-run Chinook salmon and SR steelhead (NMFS 2017b), and SR sockeye (NMFS 2015). Some populations receive special emphasis in recovery scenarios such as core populations and genetic legacy populations.

Considering the status of the ESA-listed species, all but two of the species considered in this opinion are threatened. Those two species are the UCR spring-run Chinook salmon, and SR sockeye salmon which are endangered. Most of the component populations of LCR Chinook salmon, UCR spring-run Chinook salmon, SR spring/summer-run Chinook salmon, UWR spring-run Chinook salmon, SR fall-run Chinook salmon, CR chum salmon, LCR coho salmon, SR sockeye salmon, LCR steelhead, MCR steelhead, UCR steelhead, SRB steelhead, UWR steelhead, and the Southern DPS of Pacific eulachon are at a low level of persistence. All individuals from populations of these listed species are likely to move through the action area at some point during their life history[2].

Factoring the current environmental baseline, fish from the component populations that travel through the action area encounter degraded habitat conditions: restricted natural flows, reduced water quality from substantial chemical pollution, loss of functioning floodplains and secondary channels, and loss of vegetated riparian areas and associated shoreline cover. The significance of the degradation is reflected in the limiting factors identified above including habitat access to floodplain and secondary channels, degraded shoreline/shallow water habitat, loss of spawning and rearing habitat, pollution, and increased predation. This highlights the importance of protecting current functioning habitat, limiting water quality degradation, and reducing potential predation of ESA-listed fish.

Within this context, the proposed action would create a temporary physical disturbance in the water column (via turbidity) including prop wash. Longer-term consequences will impede fish migration, provide ambush habitat for piscivorous fish, and reduce the abundance of benthic prey for juveniles. In short, we anticipate that annually a very small number of juveniles may be preyed upon (injured or killed) as a result of the structure due to piscivores using it to ambush small fish as prey. Additionally, the spuds will occupy a small area of benthic habitat, causing a slight reduction in the availability of benthic prey, which could lead to slightly reduced foraging success in a very low number of individuals.

The last element in the integration of effects includes a consideration of the cumulative effects anticipated in the action area. The recovery of aquatic habitat from the degraded baseline

[2] UWR species are not anticipated to move through the action area of WCRO-2023-03223, Barge 30/Vancouver Barge Replacement.

conditions is likely to be slow in most of the action area, and the cumulative effects (from continued or increasing uses of the action area) are likely to have a negative impact on habitat conditions. This in turn may cause negative pressure on population abundance trends in the future.

However, even when we consider the status of the threatened and endangered fish populations and degraded environmental baseline within the action area, the proposed action itself is not expected to affect the distribution, diversity, or productivity of any of the populations of ESA-listed species at a measurable level. The effects of the action would be minor and would not have a measurable impact on the affected populations. Because the proposed action would not reduce the productivity, spatial structure, or diversity of the affected populations, when combined with a degraded environmental baseline and additional pressure from cumulative effects, the action would not jeopardize the listed species considered in this opinion.

2.8. Conclusion

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the action area, the effects of the proposed action, the effects of other activities caused by the proposed action, and the cumulative effects, it is NMFS's biological opinion that the proposed action is not likely to jeopardize the continued existence of LCR Chinook salmon, UWR Chinook salmon, UCR spring-run Chinook salmon, SR spring/summer-run Chinook salmon, SR fall-run Chinook salmon, LCR coho salmon, SR sockeye salmon, CR chum salmon, LCR steelhead, UWR steelhead, MCR steelhead, UCR steelhead, SR steelhead, or the Southern DPS of Pacific eulachon or destroy or adversely modify designated critical habitat of any of the ESA-listed species considered in this opinion.

2.9. Incidental Take Statement

Section 9 of the ESA and federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is further defined by regulation to include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering (50 CFR 222.102). "Harass" is further defined by guidance as to "create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering." "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.

Portions of this proposed action are likely to result in take of Southern DPS Pacific eulachon adults, larvae, and/or eggs. Take for Southern DPS Pacific eulachon is not currently prohibited under a section 4(d) rule.

2.9.1. Amount or Extent of Take

Take in the form of harm is often impossible to quantify as a number of individuals, because the presence of the individuals (exposure to the harmful conditions) is highly variable over time, and is influenced by factors that cannot be easily predicted. Additionally, the duration of exposure is highly variable based on species behavior patterns, and the wide variability in numbers exposed and duration of exposure create a range of responses, many of which cannot be observed without research and rigorous monitoring. 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 the 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. Additionally, the NMFS knows of no device or practicable technique that would yield reliable counts of individuals that may experience these impacts. In these circumstances, we describe an "extent" of take which is a measure of the harming condition spatially, temporally, or both. The extent of take is causally related to the amount of harm that will result, and each extent of take provided below is an observable metric for monitoring, compliance, and re-initiation purposes. In summary, the extent of take for this action is defined as:

Take in the form of harm from diminished water quality during spud removal and installation. The extent of this form of take is 200 feet downstream from the point of the spud work. This extent is easily observable as a turbidity plume which is expected to reach background levels at 200 feet. This extent is causally related to the form of take because exposure of fishes in areas of excess turbidity within this area can produce deleterious behavioral responses or minor reductions in health of exposed individuals.

Take in the form of harm from the structures (and/or moored vessels) in the migratory/rearing area of salmonids over the lifespan of the structures. The extent of take equates to 35,790 square feet of overwater surface coverage caused by the presence of the 4 spud barges. This extent is readily observable, and is causally related to the form of take as predation risk increases with each structural element added in the migratory corridor.

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

2.9.2. 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.

2.9.3. Reasonable and Prudent Measures

"Reasonable and prudent measures" refer to those actions the Director considers necessary or appropriate to minimize the impact of the incidental take on the species (50 CFR 402.02).

NMFS concludes that the following reasonable and prudent measures are necessary and appropriate to minimize the impacts to listed species from construction-related actions and the long-term presence of the structure:

RPM 1: Reduce take associated with turbidity from spud removal and installation;

RPM 2: Reduce take associated with the extent of overwater structures;

RPM 3: Prepare and provide NMFS (at projectreports.wcr@noaa.gov , refer to: WCRO-2023-03223_WCRO-2024-00354) with a report describing how impacts of the incidental take on listed species in the action area will be monitored and documented within 2 months of completion of barge relocation activities.

2.9.4. Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, the federal action agency must comply (or must ensure that any applicant complies) with the following terms and conditions. The Corps 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.

1. The following terms and conditions implement reasonable and prudent measure 1:
   a. Visually monitor turbidity to ensure that it does not create a visible plume beyond 200 feet downstream of the spud work.

2. The following terms and conditions implement reasonable and prudent measure 2:
   a. Measure the surface area of the barges to ensure they do not exceed 35,790 square feet of overwater surface coverage.

3. The following terms and conditions implement all RPMs:
   a. Monitor during replacement activities for:
      i. Distressed or injured fish (including increased avian predation) during spud removal and replacement.
      ii. Downstream visible turbidity plume.
   b. Provide a report post-execution to confirm:
      i. Observations of the above criteria (distressed/injured fish, predation, turbidity).
   c. Submit reports to: projectreports.wcr@noaa.gov , labeled with the NMFS tracking number WCRO-2023-03223_WCRO-2024-00354, with attention to Curtis McFeron, Washington Coast Lower Columbia Branch.

2.10. Conservation Recommendations

Section 7(a)(1) of the ESA directs federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, “conservation recommendations” are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02). NMFS recommends to the Corps and Applicant to:

1. Install bird perching deterrence measures on the barges;
2. Develop oil spill protection measures.

2.11. Reinitiation of Consultation

This concludes formal consultation for the batched Tidewater TIC Spud Barge Replacement (Vancouver) and the Tidewater TBL Spud Barge Replacement (Kalama) projects.

Under 50 CFR 402.16(a): “Reinitiation of consultation is required and shall be requested by the federal agency, where discretionary federal involvement or control over the action has been retained or is authorized by law and: (1) If the amount or extent of taking specified in the incidental take statement is exceeded; (2) If new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) If the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion or written concurrence; or (4) If a new species is listed or critical habitat designated that may be affected by the identified action.”

2.12. “Not Likely to Adversely Affect” Determinations

Southern DPS Green Sturgeon

The only known spawning population of southern DPS green sturgeon occurs in the Sacramento River. Adults migrate into the river to spawn between April and July. Juveniles spend 1 to 4 years in freshwater before migrating to the ocean. green sturgeon could occur, but are unlikely to be present, in the action area during pile installation. During late summer and early fall, adults and subadult green sturgeon are known to congregate in large concentrations in the LCR estuary (NMFS 2021); however, most adults and subadults typically exit the LCR prior to November. Adults and subadults are strong swimmers with the speed and power to escape and avoid noise and disturbance from pile driving activities. Green sturgeon are unlikely to be affected by turbidity and suspended sediments and/or elevated sound levels. Sturgeon are typically found in turbid conditions and forage in the benthos by stirring up the sediment to access benthic prey such as burrowing shrimp and are thus relatively tolerant of higher suspended sediment concentrations. Consequently, the proposed action will have no impact on green sturgeon spawning or juvenile rearing. Additionally, the project action area does not overlap with green sturgeon critical habitat. The only impact on green sturgeon would be a slight decrease in prey resources. However, this decrease is not expected to result in harm on any individual green sturgeon as any benthic effects will be temporary and restricted to the immediate dock footprint. Therefore, the project is not likely to adversely affect green sturgeon.

3 MAGNUSON–STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT ESSENTIAL FISH HABITAT RESPONSE

Section 305(b) of the MSA directs federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. Under the MSA, this consultation is intended to promote the conservation of EFH as necessary to support sustainable fisheries and the managed species' contribution to a healthy ecosystem. For the purposes of the MSA, EFH means "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity", and includes the associated physical, chemical, and biological properties that are used by fish (50 CFR 600.10). Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects may result from actions occurring within EFH or outside of it and may include direct, indirect, site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) of the MSA also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH. Such recommendations may include measures to avoid, minimize, mitigate, or otherwise offset the adverse effects of the action on EFH (50 CFR 600.905(b))].

3.1 EFH Affected by the Proposed Action

The proposed project occurs within EFH for federally managed fish species within the Pacific Coast Salmon (Chinook and coho salmon) fishery management plan (Pacific Fishery Management Council and Pacific Coast groundfish (PFMC 2024).

3.2 Adverse Effects on EFH

NMFS determined the proposed action would adversely affect EFH as follows:

1. Temporary decrease in water quality due to increased suspended sediment and resuspended contaminants caused by spud removal and installation
2. Potential contaminant release(s)
3. Perpetuation of obstruction to migratory corridors and habitat for piscine predators due to the presence of the overwater structures and subsequent moorage of vessels

The effects listed above may affect foraging opportunity or temporarily alter migratory behaviors. The overall footprint of the barges, associated gangways, and moored vessels does not expand; however, the proposed action perpetuates the presence of the structures, facilitating a continuation of freshwater habitat and migratory passage that is permanently degraded at each structure's location within the CR.

3.3 EFH Conservation Recommendations

NMFS determined that the following conservation recommendation is necessary to avoid, minimize, mitigate, or otherwise offset the adverse effects of the proposed action on EFH.

1. NMFS recommends the Corps and Applicant assess the feasibility of incorporating additional structural/procedural best management practices for the prevention and/or reduction of predation by piscivorous birds onsite.

Fully implementing the EFH conservation recommendation would protect, by avoiding or minimizing the adverse effects described in section 3.2, above to Pacific Coast salmon.

3.4 Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, the USACE 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 the measures proposed by the agency for avoiding, minimizing, mitigating, or otherwise offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the conservation recommendations, the federal 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)).

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 the Port of Longview, Weyerhaeuser, citizens of Cowlitz, Wahkiakum, and Clark WA counties, citizens of Columbia and Multnomah OR counties and local recovery and conservation groups or organizations. Individual copies of this opinion were provided to the Corps. The document will be available at the NOAA Library Institutional Repository [https://repository.library.noaa.gov/welcome]. The format and naming adhere 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 part 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, if applicable*] 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, if applicable*], and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

5 REFERENCES

Agne, M.C., P.A. Beedlow, D.C. Shaw, D.R. Woodruff, E.H. Lee, S.P. Cline, and R.L. Comeleo. 2018. Interactions of predominant insects and diseases with climate change in Douglas-fir forests of western Oregon and Washington, U.S.A. Forest Ecology and Management 409(1). https://doi.org/10.1016/j.foreco.2017.11.004

Alizedeh, M.R., J.T. Abatzoglou, C.H. Luce, J.F. Adamowski, A. Farid, and M. Sadegh. 2021. Warming enabled upslope advance in western US forest fires. PNAS 118(22) e2009717118. https://doi.org/10.1073/pnas.2009717118

Anderson, S. C., J. W. Moore, M. M. McClure, N. K. Dulvy, and A. B. Cooper. 2015. Portfolio conservation of metapopulations under climate change. Ecological Applications 25:559-572.

Barnett, H.K., T.P. Quinn, M. Bhuthimethee, and J.R. Winton. 2020. Increased prespawning mortality threatens an integrated natural- and hatchery-origin sockeye salmon population in the Lake Washington Basin. Fisheries Research 227. https://doi.org/10.1016/j.fishres.2020.105527

Beechie, T., E. Buhle, M. Ruckelshaus, A. Fullerton, and L. Holsinger. 2006. Hydrologic regime and the conservation of salmon life history diversity. Biological Conservation, 130(4), pp.560-572.

Bisson, P. A., & Bilby, R. E. 1982. Avoidance of suspended sediment by juvenile coho salmon. North American Journal of Fisheries Management, 2(4), 371-374.

Black, B.A., P. van der Sleen, E. Di Lorenzo, D. Griffin, W.J. Sydeman, J.B. Dunham, R.R. Rykaczewski, M. García-Reyes, M. Safeeq, I. Arismendi, and S.J. Bograd. 2018. Rising synchrony controls western North American ecosystems. Global change biology, 24(6), pp. 2305-2314.

Braun, D.C., J.W. Moore, J. Candy, and R.E. Bailey. 2016. Population diversity in salmon: linkages among response, genetic and life history diversity. Ecography, 39(3), pp.317-328.

Burke, B.J., W.T. Peterson, B.R. Beckman, C. Morgan, E.A. Daly, M. Litz. 2013. Multivariate Models of Adult Pacific Salmon Returns. PLoS ONE 8(1): e54134. https://doi.org/10.1371/journal.pone.0054134

Carrasquero, J. 2001. Over-water structures: freshwater issues: Washington Department of Fish and Wildlife.

Chasco, B., I. C. Kaplan, A. Thomas, A. Acevedo-Gutiérrez, D. Noren, M. J. Ford, M. B. Hanson, J. Scordino, S. Jeffries, S. Pearson, K. N. Marshall, and E. J. Ward. 2017. Estimates of Chinook salmon consumption in Washington State inland waters by four marine mammal predators from 1970 to 2015. Canadian Journal of Fisheries and Aquatic Sciences. 74(8): 1173–1194.

Cooper, M.G., J. R. Schaperow, S. W. Cooley,S. Alam,L. C. Smith, D. P. Lettenmaier. 2018. Climate Elasticity of Low Flows in the Maritime Western U.S. Mountains. Water Resources Research. https://doi.org/10.1029/2018WR022816

Crozier, L.G., B.J. Burke, B.E. Chasco, D.L. Widener, and R.W. Zabel. 2021. Climate change threatens Chinook salmon throughout their life cycle. Communications biology, 4(1), pp.1-14.

Crozier L.G., M.M. McClure, T. Beechie, S.J. Bograd, D.A. Boughton, M. Carr, T. D. Cooney, J.B. Dunham, C.M. Greene, M.A. Haltuch, E.L. Hazen, D.M. Holzer, D.D. Huff, R.C. Johnson, C.E. Jordan, I.C. Kaplan, S.T. Lindley, N.Z. Mantua, P.B. Moyle, J.M. Myers, M.W. Nelson, B.C. Spence, L.A. Weitkamp, T.H. Williams, and E. Willis-Norton. 2019. Climate vulnerability assessment for Pacific salmon and steelhead in the California Current Large Marine Ecosystem. PLoS ONE 14(7): e0217711. https://doi.org/10.1371/journal.pone.0217711

Crozier, L. G., and J. Siegel. 2018. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2017. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region.

Crozier, L. 2017. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2016. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region.

Crozier, L. 2016. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2015. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region.

Crozier, L. 2015. Impacts of Climate Change on Columbia River Salmon: A review of the scientific literature published in 2014. Pages D1-D50 in Endangered Species Act Section 7(a)(2) supplemental biological opinion: consultation on remand for operation of the Federal Columbia River Power System. U.S. National Marine Fisheries Service, Northwest Region.

Crozier, L., R.W. Zabel, S. Achord, and E.E. Hockersmith. 2010. Interacting effects of density and temperature on body size in multiple populations of Chinook salmon. Journal of Animal Ecology. 79:342-349.

Crozier, L.G. and R.W. Zabel. 2006. Climate impacts at multiple scales: evidence for differential population responses in juvenile Chinook salmon. Journal of Animal Ecology. 75:1100-1109.

Dorner, B., M.J. Catalano, and R.M. Peterman. 2018. Spatial and temporal patterns of covariation in productivity of Chinook salmon populations of the northeastern Pacific Ocean. Canadian Journal of Fisheries and Aquatic Sciences, 75(7), pp.1082-1095.

ELS (Ecological Land Services). 2023. Biological Assessment, Tidewater Industrial Center, Spud Barge Replacement. Longview. 33 pp.

ELS. 2024. Biological Assessment, Tidewater Barge Lines, Kalama Spud Barge Replacement. Longview. 38 pp.

Eriksson, B.K., A. Sandstrom, M. Isaeus, H. Schreiber, and P. Karas. 2004. Effects of boating activities on aquatic vegetation in the Stockholm archipelago, Baltic Sea. Estuar Coast Shelf S. 61:339-349.

Fardel. A., P-E. Peyneau, B. Bechet, A. Lakel, F. Rodriguez. 2020. Performance of two contrasting pilot swale designs for treating zinc, polycyclic aromatic hydrocarbons and glyphosate from stormwater runoff. Science Total Env. 743:140503

Faler, M. P., Miller, L. M., & Welke, K. I. 1988. Effects of variation in flow on distributions of northern squawfish in the Columbia River below McNary Dam. North American Journal of Fisheries Management, 8(1), 30-35.

FitzGerald, A.M., S.N. John, T.M. Apgar, N.J. Mantua, and B.T. Martin. 2020. Quantifying thermal exposure for migratory riverine species: Phenology of Chinook salmon populations predicts thermal stress. Global Change Biology 27(3).

Ford, M. J. (editor). 2022. Biological Viability Assessment Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Pacific Northwest. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-171.

Freshwater, C., S. C. Anderson, K. R. Holt, A. M. Huang, and C. A. Holt. 2019. Weakened portfolio effects constrain management effectiveness for population aggregates. Ecological Applications 29:14.

Gliwicz, Z.M., E. Babkiewicz, R. Kumar, S. Kunjiappan, and K. Leniowski, 2018. Warming increases the number of apparent prey in reaction field volume of zooplanktivorous fish. Limnology and Oceanography, 63(S1), pp.S30-S43.

Gosselin, J. L., Buhle, E. R., Van Holmes, C., Beer, W. N., Iltis, S., & Anderson, J. J. 2021. Role of carryover effects in conservation of wild Pacific salmon migrating regulated rivers. Ecosphere, 12(7), e03618.

Gourtay, C., D. Chabot, C. Audet, H. Le Delliou, P. Quazuguel, G. Claireaux, and J.L. Zambonino-Infante. 2018. Will global warming affect the functional need for essential fatty acids in juvenile sea bass (Dicentrarchus labrax)? A first overview of the consequences of lower availability of nutritional fatty acids on growth performance. Marine Biology, 165(9), pp.1-15.

Groot, C., & Margolis, L. 1991. Pacific salmon life histories. Vancouver, Canada: UBC press.

Gustafson, R.G., M.J. Ford, D. Teel, and J.S. Drake. 2022. Status review of eulachon (Thaleichthys pacificus) in Washington, Oregon, and California. U.S. Department of Commerce. NOAA Technical Memorandum NMFS-NWFSC-105. 360 p.

Halofsky, J.E., Peterson, D.L. and B. J. Harvey. 2020. Changing wildfire, changing forests: the effects of climate change on fire regimes and vegetation in the Pacific Northwest, USA. Fire Ecology 16(4). https://doi.org/10.1186/s42408-019-0062-8

Halofsky, J.S., D.R. Conklin, D.C. Donato, J.E. Halofsky, and J.B. Kim. 2018. Climate change, wildfire, and vegetation shifts in a high-inertia forest landscape: Western Washington, U.S.A. PLoS ONE 13(12): e0209490. https://doi.org/10.1371/journal.pone.0209490

Hansel, H.C., Romine, J.G., and Perry, R.W., 2017, Acoustic tag detections of green sturgeon in the Columbia River and Coos Bay estuaries, Washington and Oregon, 2010–11: U.S. Geological Survey Open-File Report 2017-1144, 30 p., https://doi.org/10.3133/ofr20171144.

Healey, M., 2011. The cumulative impacts of climate change on Fraser River sockeye salmon (Oncorhynchus nerka) and implications for management. Canadian Journal of Fisheries and Aquatic Sciences, 68(4), pp.718-737.

Herring, S. C., N. Christidis, A. Hoell, J. P. Kossin, C. J. Schreck III, and P. A. Stott, Eds., 2018: Explaining Extreme Events of 2016 from a Climate Perspective. Bull. Amer. Meteor. Soc., 99 (1), S1–S157.

Holden, Z.A., A. Swanson, C.H. Luce, W.M. Jolly, M. Maneta, J.W. Oyler, D.A. Warren, R. Parsons and D. Affleck. 2018. Decreasing fire season precipitation increased recent western US forest wildfire activity. PNAS 115(36). https://doi.org/10.1073/pnas.1802316115

Holsman, K.K., M.D. Scheuerell, E. Buhle, and R. Emmett. 2012. Interacting effects of translocation, artificial propagation, and environmental conditions on the marine survival of Chinook Salmon from the Columbia River, Washington, USA. Conservation Biology, 26(5), pp.912-922.

ICTRT (Interior Columbia Basin Technical Recovery Team). 2007. Interior Columbia Basin TRT: Viability criteria for application to Interior Columbia Basin Salmonid ESUs. Available at http://www.nwfsc.noaa.gov/trt/trt_viability.cfm.

ICTRT. 2003. Independent populations of Chinook, steelhead, and sockeye for listed evolutionarily significant units within the Interior Columbia River domain. Working draft. July.

IPCC Working Group I (WGI). 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou editor. Cambridge University Press (https://www.ipcc.ch/report/ar6/wg1/#FullReport).

IPCC Working Group II (WGII). 2022. Climate Change 2022: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. H.O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, and B. Rama (eds.) Cambridge University Press (https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_FinalDraft_FullReport.pdf)

Isaak, D. J., & Bjornn, T. C. 1996. Movement of northern squawfish in the tailrace of a lower Snake River dam relative to the migration of juvenile anadromous salmonids. Transactions of the American Fisheries Society, 125(5), 780-793.

Isaak, D.J., C.H. Luce, D.L. Horan, G. Chandler, S. Wollrab, and D.E. Nagel. 2018. Global warming of salmon and trout rivers in the northwestern U.S.: Road to ruin or path through purgatory? Transactions of the American Fisheries Society. 147: 566-587. https://doi.org/10.1002/tafs.10059

Jacox, M. G., Alexander, M. A., Mantua, N. J., Scott, J. D., Hervieux, G., Webb, R. S., & Werner, F. E. 2018. Forcing of multi-year extreme ocean temperatures that impacted California Current living marine resources in 2016. Bull. Amer. Meteor. Soc, 99(1).

Johnson, M., T. Friesen, D. Van Doornik, D. Teel, and J. Myers. 2018. Genetic influence from hatchery stocks on upper Willamette River steelhead Oncorhynchus mykiss. Oregon Department of Fish and Wildlife. ODFW Information Report Series 2018-03.

Keefer M.L., T.S. Clabough, M.A. Jepson, E.L. Johnson, C.A. Peery, C.C. Caudill. 2018. Thermal exposure of adult Chinook salmon and steelhead: Diverse behavioral strategies in a large and warming river system. PLoS ONE 13(9): e0204274. https://doi.org/10.1371/journal.pone.0204274

Kilduff, D. P., L.W. Botsford, and S.L. Teo. 2014. Spatial and temporal covariability in early ocean survival of Chinook salmon (Oncorhynchus tshawytscha) along the west coast of North America. ICES Journal of Marine Science, 71(7), pp.1671-1682.

Koontz, E.D., E.A. Steel, and J.D. Olden. 2018. Stream thermal responses to wildfire in the Pacific Northwest. Freshwater Science, 37, 731 - 746.

Krosby, M. D.M. Theobald, R. Norheim, and B.H. McRae. 2018. Identifying riparian climate corridors to inform climate adaptation planning. PLoS ONE 13(11): e0205156. https://doi.org/10.1371/journal.pone.0205156

Lindley S.T., C.B. Grimes, M.S. Mohr, W. Peterson, J. Stein, J.T. Anderson, et al. 2009. What caused the Sacramento River fall Chinook stock collapse? NOAA Fisheries West Coast Region, Santa Cruz, CA. U.S. Department of Commerce NOAA-TM-NMFS-SWFSC-447.

Lloyd, D.S., J.P. Koenings, and J.D. LaPerriere. 1987. Effect of turbidity in fresh waters of Alaska. North American Journal of Fisheries Management 7:18-33.

Lo BP, Marlatt VL, Liao X, Reger S, Gallilee C, Ross ARS, Brown TM. Acute Toxicity of 6PPD-Quinone to Early Life Stage Juvenile Chinook (Oncorhynchus tshawytscha) and Coho (Oncorhynchus kisutch) Salmon. Environ Toxicol Chem. 2023 Apr;42(4):815-822. doi: 10.1002/etc.5568. PMID: 36692118.

Logan, D. T. 2007. Perspective on Ecotoxicology of PAHs to Fish. Human and Ecological Risk Assessment: An International Journal, 13(2), 302–316. https://doi.org/10.1080/10807030701226749

Malek, K., J.C. Adam, C.O. Stockle, and R.T. Peters. 2018. Climate change reduces water availability for agriculture by decreasing non-evaporative irrigation losses. Journal of Hydrology 561:444-460.

Martinelli, T. L., & Shively, R. S. 1997. Seasonal distribution, movements and habitat associations of northern squawfish in two lower Columbia River reservoirs. Regulated Rivers: Research & Management: An International Journal Devoted to River Research and Management, 13(6), 543-556.

McIntyre, J.K., J. Davis, C. Hinman, K.H. Macneale, B.F. Anulacion, N.L. Scholz, and J.D. Stark. 2015. Soil bioretention protects juvenile salmon and their prey from the toxic effects of urban stormwater runoff. Chemosphere, 132:213-219.

Munsch, S. H., C. M. Greene, N. J. Mantua, and W. H. Satterthwaite. 2022. One hundred-seventy years of stressors erode salmon fishery climate resilience in California's warming landscape. Global Change Biology.

Myers, J.M., J. Jorgensen, M. Sorel, M. Bond, T. Nodine, and R. Zabel. 2018. Upper Willamette River Life Cycle Modeling and the Potential Effects of Climate Change. Draft Report to the U.S. Army Corps of Engineers. Northwest Fisheries Science Center. 1 September 2018.

Newcombe, C.O. and J.T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal Fisheries Management 16:693-727.

NMFS. 2024. 2024 5-year Review: Summary & Evaluation of Upper Willamette River Steelhead, Upper Willamette River Chinook. National Marine Fisheries Service West Coast Region, Portland, OR

NMFS. 2022a. 5-Year Review: Summary & Evaluation of Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, Lower Columbia River Coho Salmon, and Lower Columbia River Steelhead. United States. National Marine Fisheries Service. West Coast Region. DOI: https://doi.org/10.25923/431f-fc96

NMFS. 2022b 5-Year Review: Summary & Evaluation of Upper Columbia River Spring-run Chinook Salmon and Upper Columbia River Steelhead. United States. National Marine Fisheries Service. West Coast Region. DOI: https://doi.org/10.25923/p4w5-dp31

NMFS. 2022c 5-Year Review: Summary & Evaluation of Upper Columbia River Spring-run Chinook Salmon and Upper Columbia River Steelhead. United States. National Marine Fisheries Service. West Coast Region. DOI: https://doi.org/10.25923/p4w5-dp31

NMFS. 2022d. 5-Year Review: Summary & Evaluation of Snake River Fall-Run Chinook Salmon United States. National Marine Fisheries Service. West Coast Region DOI: https://doi.org/10.25923/vgh6-g225

NMFS. 2022e. 5-year Review: Summary and Evaluation of Snake River Sockeye Salmon. National Marine Fisheries Service, West Coast Region. DOI: https://doi.org/10.25923/q1s6-3g66

NMFS. 2022f. 5-Year Review: Summary & Evaluation of Middle Columbia River Steelhead. United States. National Marine Fisheries Service. West Coast Region. DOI: https://doi.org/10.25923/63dr-dw24

NMFS. 2022g. 2022 5-Year Review: Summary & Evaluation of Snake River Basin Steelhead United States. National Marine Fisheries Service. West Coast Region. DOI: https://doi.org/10.25923/pxax-h320

NMFS. 2022h. 2022 5-year Review: Summary and Evaluation of Eulachon, Southern DPS. National Marine Fisheries Service, West Coast Region.

NMFS. 2021. Southern Distinct Population Segment of the North American Green Sturgeon (Acipenser medirostris) 5-Year Review: Summary and Evaluation. West Coast Region, Long Beach, California.

NMFS. 2017a. ESA Recovery Plan for Snake River Spring/Summer Chinook Salmon (Oncorhynchus tshawytscha) & Snake River Basin Steelhead (Oncorhynchus mykiss). November 2017. Portland, OR.

NMFS. 2017b. ESA Recovery Plan for Snake River Fall Chinook Salmon (Oncorhynchus tshawytscha) November 2017. Portland, OR.

NMFS. 2017c. Recovery Plan for the Southern Distinct Population Segment of Eulachon (Thaleichthys pacificus). National Marine Fisheries Service, West Coast Region, Protected Resources Division, Portland, OR, 97232.

NMFS. 2015. ESA Recovery Plan for Snake River Sockeye Salmon. West Coast Region, Protected Resources Division, Portland, OR.

NMFS. 2013. ESA Recovery Plan for Lower Columbia River coho salmon, lower Columbia River Chinook salmon, Columbia River chum salmon, and Lower Columbia River steelhead. National Marine Fisheries Service, Northwest Region. Seattle.

NMFS. 2011a. ESA Recovery Plan for Upper Willamette River Chinook Salmon and Steelhead. West Coast Region. Protected Resources Division, Portland, OR.

NMFS. 2009. Middle Columbia River steelhead distinct population segment ESA recovery plan. National Marine Fisheries Service, Northwest Region. Seattle.

NMFS. 2005. Assessment of NOAA Fisheries' critical habitat analytical review teams for 12 evolutionarily significant units of West Coast salmon and steelhead. National Marine Fisheries Service, Protected Resources Division. Portland, Oregon.

NOAA National Centers for Environmental Information (NCEI), State of the Climate: Global Climate Report for Annual 2021, published online January 2022, retrieved on February 28, 2022 from https://www.ncdc.noaa.gov/sotc/global/202113.

NWFSC (Northwest Fisheries Science Center). 2015. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest.

Ohlberger, J., E.J. Ward, D.E. Schindler, and B. Lewis. 2018. Demographic changes in Chinook salmon across the Northeast Pacific Ocean. Fish and Fisheries, 19(3), pp.533-546.

Olmos M., M.R. Payne, M. Nevoux, E. Prévost, G. Chaput, H. Du Pontavice, J. Guitton, T. Sheehan, K. Mills, and E. Rivot. 2020. Spatial synchrony in the response of a long range migratory species (Salmo salar) to climate change in the North Atlantic Ocean. Glob Chang Biol. 26(3):1319-1337. doi: 10.1111/gcb.14913. Epub 2020 Jan 12. PMID: 31701595.

Ou, M., T. J. Hamilton, J. Eom, E. M. Lyall, J. Gallup, A. Jiang, J. Lee, D. A. Close, S. S. Yun, and C. J. Brauner. 2015. Responses of pink salmon to CO2-induced aquatic acidification. Nature Climate Change 5:950-955.

PFMC. 2024. Pacific Fishery Management Council. Pacific Coast Salmon Fishery Management Plan. Feb 2024. 94p.

Quinn, T. P. 2018. The Behavior and Ecology of Pacific Salmon and Trout (2nd ed.). University of Washington Press. http://www.jstor.org/stable/j.ctvcwnvv1

Redding, J.M., C.B. Schreck, and F.H. Ev3erest. 1987. Physiological effects on coho salmon and steelhead of exposure to suspended solids. Transactions American Fisheries Society. 116:737-744.

Schindler, D. E., J. B. Armstrong, and T. E. Reed. 2015. The portfolio concept in ecology and evolution. Frontiers in Ecology and the Environment 13:257-263.

Sebring, S. H., M. C. Carper, R. D. Ledgerwood, B. P. Sandford, G. M. Mathews, and A. F. Evans. 2013. Relative vulnerability of PIT-tagged subyearling fall Chinook salmon to predation by Caspian terns and double-crested cormorants in the Columbia River estuary. Transactions of American Fisheries Society 142:1321-1334.

Servizi, J. A. and Martens D. W. 1992. Sublethal Responses of Coho Salmon (Oncorhynchus kisutch) to Suspended Sediments. Canadian Journal of Fisheries and Aquatic Sciences. 49(7): 1389-1395. https://doi.org/10.1139/f92-154.

Shafer, D. J. 1999. The effects of dock shading on the seagrass Halodule wrightii in Perdido Bay, Alabama. Estuaries. 22:936-943.

Shafer, D. J. 2002. Recommendations to minimize potential impacts to seagrasses from single family residential dock structures in the PNW. S.D. Prepared for the U.S. Army Corps of Engineers, editor.

Siegel, J., and L. Crozier. 2020. Impacts of Climate Change on Salmon of the Pacific Northwest: A review of the scientific literature published in 2019. National Marine Fisheries Service, Northwest Fisheries Science Center, Fish Ecology Division. https://doi.org/10.25923/jke5-c307

Siegel, J., and L. Crozier. 2019. Impacts of Climate Change on Salmon of the Pacific Northwest. A review of the scientific literature published in 2018. Fish Ecology Division, NWFSC. December 2019.

Spromberg JA, Baldwin DH, Damm SE, McIntyre JK, Huff M, Sloan CA, Anulacion BF, Davis JW, Scholz NL. 2015. Coho salmon spawner mortality in western US urban watersheds: bioinfiltration prevents lethal storm water impacts. J Appl Ecol. 2016 Apr;53(2):398-407. doi: 10.1111/1365-2664.12534. Epub 2015 Oct 8. PMID: 27667853; PMCID: PMC5019255.

Sridhar, V., M.M. Billah, J.W. Hildreth. 2018. Coupled Surface and Groundwater Hydrological Modeling in a Changing Climate. Groundwater Vol. 56, Issue 4. https://doi.org/10.1111/gwat.12610

Stachura, M.M., N.J. Mantua, and M.D. Scheuerell. 2014. Oceanographic influences on patterns in North Pacific salmon abundance. Canadian Journal of Fisheries and Aquatic Sciences, 71(2), pp.226-235.

Sturrock, A.M., S.M. Carlson, J.D. Wikert, T. Heyne, S. Nusslé, J.E. Merz, H.J. Sturrock and R.C. Johnson. 2020. Unnatural selection of salmon life histories in a modified riverscape. Global Change Biology, 26(3), pp.1235-1247.

Thorne, K., G. MacDonald, G. Guntenspergen, R. Ambrose, K. Buffington, B. Dugger, C. Freeman, C. Janousek, L. Brown, J. Rosencranz, J. Holmquist, J. Smol, K. Hargan, and J. Takekawa. 2018. U.S. Pacific coastal wetland resilience and vulnerability to sea-level rise. Science Advances 4(2). DOI: 10.1126/sciadv.aao3270

USOFR (U.S. Office of the Federal Register). 2011. 76 FR 65324. Endangered and Threatened Species; Designation of Critical Habitat for the Southern Distinct Population Segment of Eulachon. National Marine Fisheries Service, Department of Commerce. Final Rule. October 20, 2011. Federal Register: 76 (203): 65324-65352.

USOFR (U.S. Office of the Federal Register). 2013a. 78 FR 2893. Endangered and threatened species: Designation of a nonessential experimental population for Middle Columbia River Steelhead above the Pelton Round Butte Hydroelectric Project in the Deschutes River Basin, OR. Department of Commerce, National Oceanic and Atmospheric Administration. January 15, 2013. Federal Register 78(10):2893-2907.

USOFR (U.S. Office of the Federal Register). 2013b. 78 FR 2726. Endangered and threatened species; Designation of critical habitat for Lower Columbia River coho salmon and Puget Sound steelhead; Proposed rule. U.S Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. January 14, 2013. Federal Register 78(9):2726-2796.

USOFR (U.S. Office of the Federal Register). 2014. 79 FR 20802: Endangered and threatened wildlife; Final rule to revise the Code of Federal Regulations for species under the jurisdiction of the National Marine Fisheries Service. U.S Department of Commerce. Federal Register 79(71):20802-20817.

USOFR (U.S. Office of the Federal Register). 2019. 84 FR 53117. Notice of Initiation of 5-year reviews; request for information. National Marine Fisheries Service. U.S. Department of Commerce. October 4, 2019. Federal Register 84(193): 53117-53119.

USOFR (U.S. Office of the Federal Register). 2020a. 85 FR 16619: Endangered and Threatened Species; Extension of Public Comment Period. National Marine Fisheries Service, U.S. Department of Commerce. March 24, 2020. Federal Register 85(57):16619.

USOFR (U.S. Office of the Federal Register). 2020b. 85 FR 81822: Revisions to Hatchery Programs Included as Part of Pacific Salmon and Steelhead Species Listed Under the Endangered Species Act; final rule. National Marine Fisheries Service, U.S. Department of Commerce. 17 December 2020. Federal Register 85(243):81822–81837.

Veilleux, H.D., Donelson, J.M. and Munday, P.L., 2018. Reproductive gene expression in a coral reef fish exposed to increasing temperature across generations. Conservation physiology, 6(1), p.cox077.

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

Ward, E.J., J.H. Anderson, T.J. Beechie, G.R. Pess, M.J. Ford. 2015. Increasing hydrologic variability threatens depleted anadromous fish populations. Glob Chang Biol. 21(7):2500–9. Epub 2015/02/04. pmid:25644185.

Williams, C. R., A. H. Dittman, P. McElhany, D. S. Busch, M. T. Maher, T. K. Bammler, J. W. MacDonald, and E. P. Gallagher. 2019. Elevated CO2 impairs olfactory-mediated neural and behavioral responses and gene expression in ocean-phase coho salmon (Oncorhynchus kisutch). 25:963-977.

Williams, T.H., B.C. Spence, D.A. Boughton, R.C. Johnson, L.G. Crozier, N.J. Mantua, M.R. O’Farrell, and S.T. Lindley. 2016. Viability assessment for Pacific salmon and steelhead listed under the Endangered Species Act: Southwest. NOAA Fisheries Southwest Fisheries Science Center, Santa Cruz, CA: U.S. Dep Commerce NOAA Tech Memo NMFS SWFSC 564.

Wissmar, R.C., J.E. Smith, B.A. McIntosh, H.W. Li, G.H. Reeves, and J.R. Sedell. 1994. Ecological health of river basins in forested regions of eastern Washington and Oregon. General Technical Report PNW-GTR-326, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Portland, Oregon.

Yan, H., N. Sun, A. Fullerton, and M. Baerwalde. 2021. Greater vulnerability of snowmelt-fed river thermal regimes to a warming climate. Environmental Research Letters 16(5). https://doi.org/10.1088/1748-9326/abf39