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 Consultation No.:
WCRO-2018-00284

June 8, 2020

David Williams
Director, USDA Wildlife Services
6135 NE 80th
Suite A-8
Portland, Oregon 97218

Re: Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for USDA Wildlife Service's Semiaquatic Mammal Damage Management Activities in Oregon.

Dear Mr. Williams:

Thank you for your letter of May 2, 2018, 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 United States Department of Agriculture (USDA) Wildlife Service's Semiaquatic Mammal Damage Management activities in Oregon carried out under your authority from the Animal Damage Control Act of March 2, 1931, as amended (7 U.S.C. 426-426c; 46 Stat. 1468). This consultation was conducted in accordance with the 2019 revised regulations that implement section 7 of the ESA (50 CFR 402, 84 FR 45016).

In this opinion, we concluded the proposed actions are not likely to jeopardize the continued existence of the following ESA-listed species, or result in the destruction or adverse modification of their proposed or designated critical habitats:

1. Lower Columbia River (LCR) Chinook salmon (*Oncorhynchus tshawytscha*)
2. Upper Willamette River (UWR) Chinook salmon
3. Snake River (SR) spring/summer-run Chinook salmon
4. SR fall-run Chinook salmon
5. Columbia River (CR) chum salmon (*O. keta*)
6. LCR coho salmon (*O. kisutch*)
7. Oregon Coast (OC) coho salmon
8. Southern Oregon/Northern California Coast (SONCC) coho salmon
9. LCR steelhead (*O. mykiss*)
10. UWR steelhead
11. Middle Columbia River (MCR) steelhead
12. Snake River Basin (SRB) steelhead

As required by section 7 of the ESA, we are providing an incidental take statement (ITS) with the opinion. The ITS describes reasonable and prudent measures NMFS considers necessary or appropriate to minimize the impact of incidental take associated with -WS-Oregon's activities. The ITS also sets forth nondiscretionary terms and conditions, including reporting requirements, that the Federal action agencies must comply with to carry out the reasonable and prudent measures. Incidental take from actions that meet these terms and conditions will be exempt from the ESA's prohibition against the take of the listed species considered in this opinion.

We concur with USDA's determination or determined on our own the proposed actions may affect but are not likely to adversely affect the following ESA-listed species or their designated critical habitats:

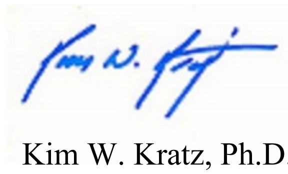
1. Upper Columbia River (UCR) spring-run Chinook
2. UCR steelhead
3. SR sockeye salmon (*O. nerka*)
4. Southern distinct population segment Pacific eulachon (*Thaleichthys pacificus*)
5. Southern distinct population segment green sturgeon (*Acipenser medirostris*)

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 (16 U.S.C. 1855(b)), and concluded that the action would adversely affect the EFH of Pacific Coast salmon species. We have included the results of that review in Section 3 of this document, including three conservation recommendations to avoid, minimize, or otherwise offset potential adverse effects on EFH.

Section 305(b)(4)(B) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) requires Federal agencies to provide a detailed written response to NMFS within 30 days after receiving these recommendations. If the response is inconsistent with the EFH conservation recommendations, the action agency must explain why the recommendations will not be followed, including the scientific justification for any disagreements over the effects of the activities and the recommendations. In response to increased oversight of overall EFH program effectiveness by the Office of Management and Budget, we established a quarterly reporting requirement for ourselves to determine how many conservation recommendations are provided as part of each EFH consultation and how many are adopted by the action agency. Therefore, we request that in your statutory reply to the EFH portion of this consultation, you clearly identify the number of conservation recommendations accepted.

Please direct questions regarding this opinion to Chuck Wheeler at 541.957.3379 of my staff in the Oregon Coast Branch of the Oregon Washington Coastal Office.

Sincerely,



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

cc: Kevin Christensen, USDA WS

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

USDA Wildlife Service's Semiaquatic Mammal Damage Management in Oregon

NMFS Consultation Number: WCRO-2018-00284

Action Agency: USDA Wildlife Services

Affected Species and NMFS' Determinations:

ESA-Listed Species	Status	Is the action likely to adversely affect this species or its critical habitat?	Is the action likely to jeopardize this species?	Is action likely to destroy or adversely modify critical habitat for this species?
Lower Columbia River Chinook salmon	T	Yes	No	No
Upper Willamette River Chinook salmon	T	Yes	No	No
Upper Columbia River spring-run Chinook salmon	E	No	N/A	N/A
Snake River spring/summer run Chinook salmon	T	Yes	No	No
Snake River fall-run Chinook salmon	T	Yes	No	No
Columbia River chum salmon	T	Yes	No	No
Lower Columbia River coho salmon	T	Yes	No	No
Oregon Coast coho salmon	T	Yes	No	No
Southern Oregon/Northern California Coast coho salmon	T	Yes	No	No
Snake River sockeye salmon	E	No	N/A	N/A
Lower Columbia River steelhead	T	Yes	No	No
Upper Willamette River steelhead	T	Yes	No	No
Middle Columbia River steelhead	T	Yes	No	No
Upper Columbia River steelhead	T	No	N/A	N/A
Snake River Basin steelhead	T	Yes	No	No
Green sturgeon	T	No	N/A	N/A
Eulachon	T	No	N/A	N/A

Fishery Management Plan That Describes EFH in the Project Area	Would the action adversely affect EFH?	Are EFH conservation recommendations provided?
Pacific Coast Salmon	Yes	Yes

Consultation Conducted By: National Marine Fisheries Service, West Coast Region

Issued By:

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

Date: June 8, 2020

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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 USC 1531 et seq.), and implementing regulations at 50 CFR 402.

We also completed an essential fish habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR 600.

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

1.2 Consultation History

In response to a November 2, 2017 Notice of Intent to Sue for failing to consult under the ESA, the U.S. Department of Agriculture Animal and Plant Health Inspection Service Wildlife Services (WS-Oregon) sent a letter to NMFS on December 22, 2017, requesting consultation pursuant to Section 7 of the Endangered Species. On December 27, 2017, pending completion of ESA consultation, WS-Oregon suspended their Semiaquatic Mammal Damage Management activities in Oregon.

On January 18, 2018, we met with WS-Oregon to discuss their activities in Oregon, and the ESA consultation process. Starting in March 2018, NMFS staff attended multiple site visits with WS-Oregon staff to better understand the proposed action and how WS-Oregon implements their activities in Oregon. After several conference calls and individual telephone conversations, WS-Oregon sent a biological assessment (BA) on May 2, 2018. On May 7, 2018, we agreed to initiate consultation. During the consultation process, we worked with WS-Oregon to geo-reference their historical data and overlay it on a GIS coverage of streams. Because of the time needed for this analysis, we requested a 90-day extension of the consultation timeline on September 26, 2018. WS-Oregon agreed to the new schedule on September 28, 2018. On November 8, 2019, WS-Oregon received a draft biological opinion from NMFS. WS-Oregon returned the draft opinion with comments on April 24, 2020.

WS-Oregon concluded the proposed action “may affect, and is likely to adversely affect” the following ESA-listed species and their designated critical habitats:

1. Lower Columbia River (LCR) Chinook salmon (*Oncorhynchus tshawytscha*)
2. Upper Willamette River (UWR) Chinook salmon
3. Snake River (SR) spring/summer-run Chinook salmon
4. SR fall-run Chinook salmon
5. Columbia River (CR) chum salmon (*O. keta*)
6. LCR coho salmon (*O. kisutch*)
7. Oregon Coast (OC) coho salmon
8. Southern Oregon/Northern California Coast (SONCC) coho salmon
9. SR sockeye salmon (*O. nerka*)
10. LCR steelhead (*O. mykiss*)
11. UWR steelhead
12. Middle Columbia River (MCR) steelhead
13. Snake River Basin (SRB) steelhead

WS-Oregon concluded the proposed action "may affect, and is not likely to adversely affect" the following ESA-listed species and their designated critical habitats:

1. Southern distinct population segment Pacific eulachon (eulachon)(*Thaleichthys pacificus*)
2. Southern distinct population segment green sturgeon (green sturgeon)(*Acipenser medirostris*)

WS-Oregon did not make a determination for the following ESA-listed species and their designated critical habitats:

1. Upper Columbia River (UCR) spring-run Chinook salmon
2. UCR steelhead

Our concurrence with WS-Oregon's conclusion that the proposed action "may affect, and is not likely to adversely affect" eulachon, green sturgeon, or their designated critical habitats is documented in the "Not Likely to Adversely Affect" Determinations section 2.12. In conducting our effects analysis, we determined all the effects to SR sockeye salmon and the two species WS-Oregon did not make a determination for are either so small in size (cannot be meaningfully measured, detected, or evaluated), or are so extremely unlikely, that they met the threshold for "not likely to adversely affect." The documentation in section 2.12 provides our explanation as to why all the effects are insignificant and/or discountable. We included UCR spring-run Chinook salmon and UCR steelhead because they occur within the action area and are potentially exposed to the effects of the action.

1.3 Proposed Federal Action

"Action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies (50 CFR 402.02). WS-Oregon proposes to carry out their semiaquatic mammal activities in Oregon into the future. WS-Oregon's activities (described more fully in section 3 of the BA which is incorporated here by reference) is a collection of cooperative activities with other federal, tribal, state, local agencies, private individuals, and associations to protect agriculture, natural resources, property, and human safety from wildlife threats and damages. The primary statutory authority for Animal and Plant Health Inspection Service (APHIS)-WS is the Animal Damage Control Act of March 2, 1931, as amended (7 U.S.C. 8351; 46 Stat. 1468). WS-Oregonwill address damage and conflicts caused by beaver (*Castor canadensis*), mink (*Mustela vison*), muskrat (*Ondatra zibethicus*), nutria (*Myocastor coypus*), and river otter (*Lutra canadensis*). We considered, under the ESA, whether or not the proposed action would cause any other activities and determined that it would not.

APHIS-WS uses an integrated and adaptive approach to reducing human-wildlife conflict by providing technical assistance (education, information and advice) and operational wildlife damage management using a wide variety of strategies and tools. Management is directed toward individual offending animals and/or localized groups, depending on the circumstances, to reduce the conflict between wildlife and people. WS-Oregon's proposed action is not intended to reduce wildlife populations. The most effective approach to resolving wildlife damage is to integrate the use of several management methods simultaneously or sequentially. Integrated wildlife damage management (IWDM) draws from the largest possible array of options to create a combination of wildlife management techniques appropriate for the specific circumstances. IWDM may incorporate cultural practices (i.e., removal of artificial food sources), habitat modification, animal behavior (i.e., scaring), removing local individuals or groups, or any combination of these, depending on the characteristics of the specific damage problems.

The methods used by APHIS-WS include providing technical assistance recommendations such as fencing, water-level control devices, and other exclusionary barriers, and direct control methods such as shooting, poisoning, and trapping with foothold traps, cage traps, quick-kill/body gripping traps, suitcase traps, and cable restraining devices. When APHIS-WS receives a request for assistance, trained and experienced field agents determine the appropriate IWDM methods to recommend and/or implement by using the APHIS-WS Decision Model (Slate *et al*. 1992, WS 2014; hereafter called the "Decision Model"; Figure 1). Using this Decision Model, the field agent assesses the problem and evaluates the effectiveness of the various methods available for IWDM. The field agent then recommends a strategy based on a variety of factors, including short-term and long-term effectiveness of the method, possible restrictions due to laws, regulations, or site-specific conditions, environmental considerations, and cost. APHIS-WS provides the assistance and the field agent and/or the requestor monitors the effectiveness of the employed methods. Management strategies are adjusted, modified, or discontinued, as needed, depending on the agent's evaluation of the results.

Figure 1. APHIS-WS Decision Model

WS-Oregon is cooperatively funded and has limited funding. Therefore, requestors are asked, and expected, to implement methods when they are able to. This reduces their need for WS-Oregon's efforts. This allows WS-Oregon's efforts to be focused on activities the requestor is less skilled or equipped to do, such as lethal control actions. WS-Oregon documents their responses to requests in a database called the Management Information System.

WS-Oregon will provide technical assistance and/or direct control. Technical assistance is generally provided following an on-site visit or verbal consultation with the requestor. Several management strategies are described to the requestor for short- and long-term solutions to damage problems. Direct control includes activities conducted or supervised by WS-Oregon personnel. Direct control assistance is implemented when the problem cannot effectively be resolved through technical assistance or through the requestor's own ability.

WS-Oregon field agents employ lethal and non-lethal methods. Non-lethal methods are primarily preventative practices, such as barriers to restrict animal access, water-level control devices, and other deterrents. In addition, WS-Oregon may opt for using live traps, so captured animals can be relocated. WS-Oregon will consider relocation of semiaquatic mammals, excluding nutria. Though this practice is rare due to many factors, including the difficulty in receiving authorization from the Oregon Department of Fish and Wildlife (ODFW). WS-Oregon uses cable devices, zinc phosphide, firearms, quick-kill/body gripping traps, and foothold traps for lethal removal.

In order to evaluate the scope of the proposed action, WS-Oregon worked with us to analyze beaver removals over a 5-year analysis period of 2013-2017.[1] This process entailed: [2]

1. WS-Oregon querying their field agents' and records of beaver removal sites;
2. WS-Oregon plotting data from #1 geospatially, grouping individual removals within 200 feet of each other into removal sites;
3. NMFS constructing and providing a GIS coverage of stream reaches containing ESA-listed species, designated critical habitat, or designated EFH within the action area (hereafter called NMFS Trust Resource streams); and
4. WS-Oregon determining how many sites from #2 were on streams from #3.[3]

While this approach likely overestimates the potential impact of the proposed action on ESA-listed salmonids and their critical habitats, it is a conservative approach giving the benefit of doubt to the listed species. Furthermore, some of the sites WS-Oregon counted are in areas where beavers will not build dams due to site constraints (i.e., stream channels greater than 33 feet wide [Suzuki and McComb 1998] and in lakes).

Over the 5-year analysis period, WS-Oregon removed beaver from a total of 66 sites (an average of about 13 sites per year) on NMFS Trust Resource streams in Oregon (Table 1).

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[1] WS suspended beaver removal at the end of 2017, making 2012-2017 the most recent 5-year period of operation.

[2] For full description of WS's methods, see February 15, 2019 email from Kevin Christensen (WS) to Chuck Wheeler (NMFS) delivering the data to NMFS.

[3] WS counted any removal site falling within 200 feet of a NMFS Trust Resource stream as being a removal from a NMFS Trust Resource stream because we found the line data for NMFS Trust Resource streams does not follow actual stream location perfectly and WS's data plotting process was imprecise given the sites were plotted after the fact.

Table 1. The number of sites Wildlife Services removed beaver from NMFS Trust Resource streams during the analysis period, along with the number of HUC5s they were removed from and the total number of HUC5s per ESU/DPS.[4]

ESU/D`PS	Number of beaver removal sites	Number of HUC5s where beaver were removed	Number of HUC5s in the ESU/DPS
LCR Chinook salmon	0	0	25
UWR Chinook salmon	4	4	59
SR spring/summer Chinook salmon	0	0	34
SR fall Chinook salmon	0	0	7
CR chum salmon	0	0	11
LCR coho salmon	0	0	29
OC coho salmon	62	27	78
SONCC coho salmon	0	0	36
LCR steelhead	0	0	20
UWR steelhead	4	4	38
MCR steelhead	0	0	85
SR steelhead	0	0	33

During the analysis period, WS-Oregon removed beaver from 22 sites (approximately 4 per year) on NMFS Trust Resource streams in one HUC5 watershed (Coquille River HUC# 1710030505, which contains OC coho salmon). No other HUC5 watershed had more than four removal sites from NMFS Trust Resource streams, with 27 of the 31 HUC5 watersheds having only 1 or 2 removals (Figure 2).

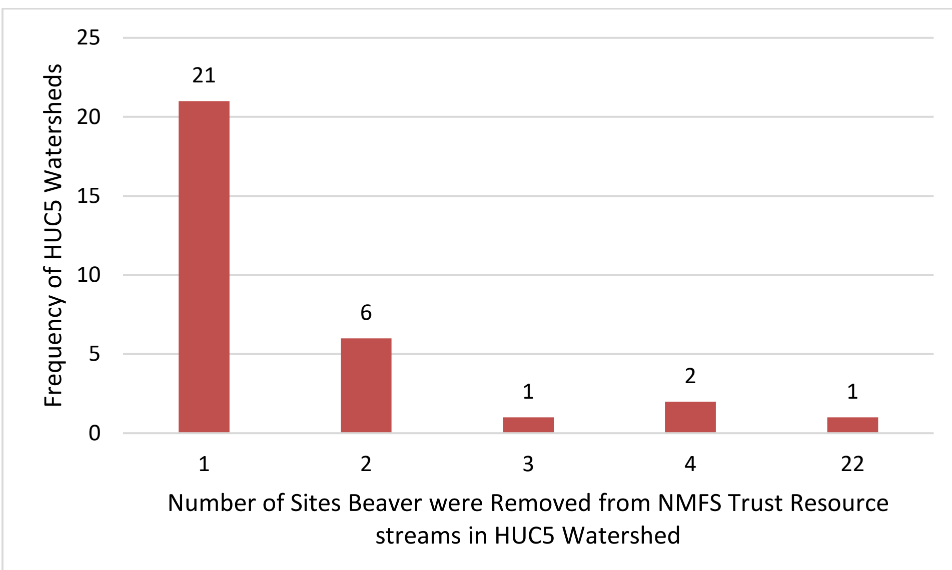

Figure 2. Histogram of HUC5 watersheds where beaver were removed from NMFS Trust Resource streams during the 5-year analysis period.

[4] Because some ESU/DPSs overlap, some removal sites count towards more than one ESU/DPS.

For the rest of our analysis, we assume these numbers reflect future removals (i.e. in any 5-year period, no more than 66 total removal sites on NMFS Trust Resource streams with no more than 22 in the Coquille River HUC5 and no more than 4 in any other HUC5). We also assume the distribution of sites will be similar, but not exact. We expect a few removals in HUC5s and ESU/DPSs where there were none during the analysis period.

WS-Oregon also removed beaver from 320 sites not on NMFS Trust Resources streams but within HUC5 watersheds that contain NMFS Trust Resources (Table 2). These removal sites may be upstream of listed species and critical habitats, but may also be in irrigation ditches or off channel ponds. Some of these removals will have effects on listed species and critical habitat, including those on water quantity, sediment, and water temperature. In this analysis, we consider the effects from removing beaver from sites not on NMFS Trust Resource streams. Though, we focus our analysis on removing beaver from NMFS Trust Resource streams because the preponderance of effects to ESA species and critical habitats will originate at those sites. While not always specifically discussed, we are also accounting for the effects of WS-Oregon removing beavers upstream from NMFS Trust Resource streams.

Table 2. The number of sites not on NMFS Trust Resource streams WS-Oregon removed beaver during the analysis period, along with the number of HUC5s they were removed from and the total number of HUC5s per ESU/DPS.[5]

ESU/DPS	Number of beaver removal sites	Number of HUC5s where beaver were removed	Number of HUC5s in the ESU/DPS
LCR Chinook salmon	10	3	25
UWR Chinook salmon	88	29	59
SR spring/summer Chinook salmon	2	2	34
SR fall Chinook salmon	0	0	7
CR chum salmon	0	0	11
LCR coho salmon	6	2	29
OC coho salmon	142	33	78
SONCC coho salmon	7	6	36
LCR steelhead	6	2	20
UWR steelhead	134	27	38
MCR steelhead	13	12	85
SR steelhead	2	2	33

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

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, each Federal agency must ensure that its actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. Per the requirements of the ESA, Federal action agencies consult with NMFS and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provides an

[5] Because some ESU/DPSs overlap, some removal sites count towards more than one ESU/DPS.

opinion stating how the agency's actions would affect listed species and their critical habitats. If incidental take is reasonably certain to occur, section 7(b)(4) requires NMFS to provide an ITS that specifies the impact of any incidental taking and includes non-discretionary reasonable and prudent measures (RPMs) and terms and conditions to minimize such impacts.

2.1 Analytical Approach

This biological opinion includes both a jeopardy analysis and an adverse modification analysis. The jeopardy analysis relies upon the regulatory definition of "to jeopardize the continued existence of" a listed species, which is "to engage in an action that 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 CFR402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species.

This biological opinion relies on the definition of "destruction or adverse modification," which means "a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species" (50 CFR 402.02).

The designation(s) of critical habitat for (species) use(s) the term primary constituent element (PCE) or essential features. The 2016 critical habitat regulations (50 CFR 424.12) replace this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a ''destruction or adverse modification'' analysis, which is the same regardless of whether the original designation identified PCEs, PBFs, or essential features. In this biological opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

The 2019 regulations define effects of the action using the term "consequences" (50 CFR 402.02). As explained in the preamble to the regulations (84 FR 44977), that definition 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:

- Identify the rangewide status of the species and critical habitat expected to be adversely affected by the proposed action.
- Describe the environmental baseline in the action area.
- Analyze the effects of the proposed action on both species and their habitat using an "exposure-response-risk" approach.
- Describe any cumulative effects in the action area.
- Integrate and synthesize the above factors by: (1) Reviewing the status of the species and critical habitat; and (2) adding the effects of the action, the environmental baseline, and cumulative effects to assess the risk that the proposed action poses to species and critical habitat.

- Reach a conclusion about whether species are jeopardized or critical habitat is adversely modified.
- If necessary, suggest a reasonable and prudent alternative 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 function of the essential PBFs that help to form that conservation value.

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

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

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

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

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

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

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

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

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

2.2.1 Status of the 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 PBFs 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.

A summary of the status of critical habitats, considered in this opinion, is provided in Table 3, below. Critical habitat status documents are incorporated by reference.

Table 3. 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 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 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.
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.
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.

Species	Designation Date and Federal Register Citation	Critical Habitat Status Summary
Oregon Coast coho salmon	2/11/08 73 FR 7816	Critical habitat encompasses 13 subbasins in Oregon. The long-term decline in Oregon Coast coho salmon productivity reflects deteriorating conditions in freshwater habitat as well as extensive loss of access to habitats in estuaries and tidal freshwater. Many of the habitat changes resulting from land use practices over the last 150 years that contributed to the ESA-listing of Oregon Coast coho salmon continue to hinder recovery of the populations; changes in the watersheds due to land use practices have weakened natural watershed processes and functions, including loss of connectivity to historical floodplains, wetlands and side channels; reduced riparian area functions (stream temperature regulation, wood recruitment, sediment and nutrient retention); and altered flow and sediment regimes (NMFS 2016a). Several historical and ongoing land uses have reduced stream capacity and complexity in Oregon coastal streams and lakes through disturbance, road building, splash damming, stream cleaning, and other activities. Beaver removal, combined with loss of large wood in streams, has also led to degraded stream habitat conditions for coho salmon (Stout *et al*. 2012)
Southern Oregon/Northern California Coast coho salmon	5/5/99 64 FR 24049	Critical habitat includes all areas accessible to any life-stage up to long-standing, natural barriers and adjacent riparian zones. SONCC coho salmon critical habitat within this geographic area has been degraded from historical conditions by ongoing land management activities. Habitat impairments recognized as factors leading to decline of the species that were included in the original listing notice for SONCC coho salmon include: 1) Channel morphology changes; 2) substrate changes; 3) loss of in-stream roughness; 4) loss of estuarine habitat; 5) loss of wetlands; 6) loss/degradation of riparian areas; 7) declines in water quality; 8) altered stream flows; 9) fish passage impediments; and 10) elimination of habitat
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.
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.

2.2.2 Status of the Species

Table 4, 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. These documents are available on the NMFS West Coast Region website (http://www.westcoast.fisheries.noaa.gov/) and are incorporated by reference.

Table 4. Listing classification and date, recovery plan reference, most recent status review, status summary, and limiting factors for each species considered in this opinion. Acronyms appearing in the table include DPS (Distinct Population Segment), ESU (Evolutionarily Significant Unit), MPG (Multiple Population Grouping), NWFSC (Northwest Fisheries Science Center), and VSP (Viable Salmonid Population).

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	NWFSC 2015	This ESU comprises 32 independent populations. Twenty-seven populations are at very high risk of extinction, 2 populations are at high risk, one population is at moderate risk, and 2 populations are at very low risk. Overall, there was little change since the last status review in the biological status of this ESU, although there are some positive trends. Increases in abundance were noted in about 70% of the fall-run populations and decreases in hatchery contribution were noted for several populations. Relative to baseline VSP levels identified in the recovery plan, 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.	• 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 Willamette River Chinook salmon	Threatened 6/28/05	NMFS 2011	NWFSC 2015	This ESU comprises seven populations. Five populations are at very high risk of extinction, one population is at moderate risk (Clackamas River) and one population is at low risk (McKenzie River). Consideration of data collected since the last status review in 2010 indicates the fraction of hatchery origin fish in all populations remains high (even in Clackamas and McKenzie populations). The proportion of natural origin spawners improved in the North and South Santiam basins, but is still well below identified recovery goals. Abundance levels for five of the seven populations remain well below their recovery goals. Of these, the Calapooia River may be functionally extinct and the Molalla River remains critically low. Abundances in the North and South Santiam rivers have risen since the 2010 review, but still	• 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

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
				range only in the high hundreds of fish. The Clackamas and McKenzie populations have previously been viewed as natural population strongholds, but have both experienced declines in abundance despite having access to much of their historical spawning habitat. Overall, populations appear to be at either moderate or high risk, there has been likely little net change in the VSP score for the ESU since the last review, so the ESU remains at moderate risk.	
Snake River spring/summer-run Chinook salmon	Threatened 6/28/05	NMFS 2016b	NWFSC 2015	This ESU comprises 28 extant and four extirpated populations. All except one extant population (Chamberlin Creek) are at high risk of extinction. Natural origin abundance has increased over the levels reported in the prior status review for most populations in this ESU, although the increases were not substantial enough to change viability ratings. Relatively high ocean survivals in recent years were a major factor in recent abundance patterns. While there have been improvements in abundance and productivity in several populations relative to prior reviews, those changes have not been sufficient to warrant a change in the ESU's threatened status.	• Degraded freshwater habitat • Effects related to the hydropower system in the mainstem Columbia River, • Altered flows and degraded water quality • Harvest-related effects • Predation
Snake River fall-run Chinook salmon	Threatened 6/28/05	NMFS 2015	NWFSC 2015	This ESU has one extant population. Historically, large populations of fall Chinook salmon spawned in the Snake River upstream of the Hells Canyon Dam complex. The extant population is at moderate risk of extinction for both diversity and spatial structure and abundance and productivity. The overall viability rating for this population is 'viable.' Overall, the status of Snake River fall Chinook salmon has clearly improved compared to the time of listing and compared to prior status reviews. The single extant population in the ESU is currently meeting the criteria for a rating of 'viable' developed by the Interior Columbia Technical Recovery Team, but the ESU as a whole is not	• 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
				meeting the recovery goals described in the recovery plan for the species, which require the single population to be "highly viable with high certainty" and/or will require reintroduction of a viable population above the Hells Canyon Dam complex.	
Columbia River chum salmon	Threatened 6/28/05	NMFS 2013	NWFSC 2015	Overall, the status of most chum salmon populations is unchanged from the baseline VSP scores estimated in the recovery plan. A total of 14 of 17 populations require a higher level of viability, with most requiring substantial improvements to reach their viability goals. Even with the improvements observed during the last five years, the majority of populations in this ESU remain at a high or very high risk of extinction and considerable progress remains to be made to achieve the recovery goals.	• 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	NWFSC 2015	Of the 24 populations that make up this ESU, 21 populations are at very high risk of extinction, 1 population is at high risk, and 2 populations are at moderate risk. Recent recovery efforts may have contributed to the observed natural production, but in the absence of longer term data sets it is not possible to parse out these effects. Populations with longer term data sets exhibit stable or slightly positive abundance trends. Some trap and haul programs appear to be operating at or near replacement, although other programs still are far from that threshold and require supplementation with additional hatchery-origin spawners .Initiation of or improvement in the downstream juvenile facilities at Cowlitz Falls, Merwin, and North Fork Dam are likely to further improve the status of the associated upstream populations. While	• 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
				these and other recovery efforts have likely improved the status of a number of coho salmon populations, abundances are still at low levels and the majority of the populations remain at moderate or high risk. For the Lower Columbia River region land development and increasing human population pressures will likely continue to degrade habitat, especially in lowland areas. Although populations in this ESU have generally improved, especially in the 2013/14 and 2014/15 return years, recent poor ocean conditions suggest that population declines might occur in the upcoming return years	
Oregon Coast coho salmon	Threatened 6/20/11; reaffirmed 4/14/14	NMFS 2016a	NWFSC 2015	This ESU comprises 56 populations including 21 independent and 35 dependent populations. The last status review indicated a moderate risk of extinction. Significant improvements in hatchery and harvest practices have been made for this ESU. Most recently, spatial structure conditions have improved in terms of spawner and juvenile distribution in watersheds; none of the geographic area or strata within the ESU appear to have considerably lower abundance or productivity. The ability of the ESU to survive another prolonged period of poor marine survival remains in question.	• Reduced amount and complexity of habitat including connected floodplain habitat • Degraded water quality • Blocked/impaired fish passage • Inadequate long-term habitat protection • Changes in ocean conditions
Southern Oregon/ Northern California Coast coho salmon	Threatened 6/28/05	NMFS 2014	NMFS 2016c	This ESU comprises 31 independent, 9 independent, and 5 ephemeral populations all grouped into 7 diversity strata. Of the 31 independent populations, 24 are at high risk of extinction and 6 are at moderate risk of extinction. The extinction risk of an ESU depends upon the extinction risk of its constituent independent populations; because the population abundance of most independent populations are below their depensation threshold, the SONCC coho salmon ESU is at high risk of extinction and is not viable	• Lack of floodplain and channel structure • Impaired water quality • Altered hydrologic function • Impaired estuary/mainstem function • Degraded riparian forest conditions • Altered sediment supply • Increased disease/predation/competition • Barriers to migration • Fishery-related effects • Hatchery-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	NWFSC 2015	This DPS comprises 23 historical populations, 17 winter-run populations and six summer-run populations. Nine populations are at very high risk of extinction, 7 populations are at high risk, 6 populations are at moderate risk, and 1 population is at low risk. The majority of winter-run steelhead populations in this DPS continue to persist at low abundances. Hatchery interactions remain a concern in select basins, but the overall situation is somewhat improved compared to prior reviews. Summer-run steelhead populations were similarly stable, but at low abundance levels. The decline in the Wind River summer-run population is a source of concern, given that this population has been considered one of the healthiest of the summer-runs; however, the most recent abundance estimates suggest that the decline was a single year aberration. Passage programs in the Cowlitz and Lewis basins have the potential to provide considerable improvements in abundance and spatial structure, but have not produced self-sustaining populations to date. Even with modest improvements in the status of several winter-run DIPs, none of the populations appear to be at fully viable status, and similarly none of the MPGs meet the criteria for viability.	• 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 2011	NWFSC 2015	This DPS has four demographically independent populations. Three populations are at low risk of extinction and one population is at moderate risk. Declines in abundance noted in the last status review continued through the period from 2010-2015. While rates of decline appear moderate, the DPS continues to demonstrate the overall low abundance pattern that was of concern during the last status review. The causes of these declines are not well understood, although much accessible habitat is degraded and under continued development pressure. The elimination of winter-run hatchery release in the basin reduces hatchery threats, but non-native summer	• 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

Species	Listing Classification and Date	Recovery Plan Reference	Most Recent Status Review	Status Summary	Limiting Factors
				steelhead hatchery releases are still a concern for species diversity and a source of competition for the DPS. While the collective risk to the persistence of the DPS has not changed significantly in recent years, continued declines and potential negative impacts from climate change may cause increased risk in the near future.	• Altered population traits due to interbreeding with hatchery origin fish
Middle Columbia River steelhead	Threatened 1/5/06	NMFS 2009	NWFSC 2015	This DPS comprises 17 extant populations. The DPS does not currently include steelhead that are designated as part of an experimental population above the Pelton Round Butte Hydroelectric Project. Returns to the Yakima River basin and to the Umatilla and Walla Walla Rivers have been higher over the most recent brood cycle, while natural origin returns to the John Day River have decreased. There have been improvements in the viability ratings for some of the component populations, but the DPS is not currently meeting the viability criteria in the MCR steelhead recovery plan. In general, the majority of population level viability ratings remained unchanged from prior reviews for each major population group within the DPS.	• 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 2016b	NWFSC 2016	This DPS comprises 24 populations. Two populations are at high risk of extinction, 15 populations are rated as maintained, 3 populations are rated between high risk and maintained, 2 populations are at moderate risk, 1 population is viable, and 1 population is highly viable. Four out of the five MPGs are not meeting the specific objectives in the recovery plan based on the updated status information available for this review, and the status of many individual populations remains uncertain A great deal of uncertainty still remains regarding the relative proportion of hatchery fish in natural spawning areas near major hatchery release sites within individual populations.	• 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

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 proposed WS-Oregon activities occur at sites throughout the State of Oregon. Therefore, the action area includes estuarine and riverine waters in Oregon (including the adjacent floodplain) occupied by ESA-listed salmonids and/or designated as critical habitat.

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 consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline (50 CFR 402.02).

As described above in the Status of the Species and Critical Habitat sections, factors that limit the recovery of species considered in this opinion vary with the overall condition of aquatic habitats on surrounding lands. Within the action area, many stream and riparian areas have been degraded by the effects of land and water use, including road construction, forest management, agriculture, mining, transportation, urbanization, and water development. Each of these economic activities has contributed to the myriad factors for the decline of species in the action area. Among the most important of these are changes in stream channel morphology, degradation of spawning substrates, reduced instream roughness and cover, loss and degradation of estuarine rearing habitats, loss of wetlands, loss and degradation of riparian areas, water quality (*e.g.*, temperature, sediment, dissolved oxygen, contaminants) degradation, blocked fish passage, direct take, and loss of habitat refugia. Climate change is likely to play an increasingly important role in determining the abundance of ESA-listed species, and the conservation value of designated critical habitats, in the Pacific Northwest.

West of the Cascade Mountains in Oregon, stream habitats and riparian areas have been degraded by road construction, timber harvest, splash damming, urbanization, agricultural activities, mining, flood control, filling of estuaries, and construction of dams (NMFS 2011, NMFS 2016a). East of the Cascade Mountains, aquatic habitats have been degraded by road building, timber harvest, splash damming, livestock grazing, water withdrawal, agricultural activities, mining, urbanization, and construction of reservoirs and dams (NMFS 2009, NMFS 2016b). WS-Oregon has typically removed beaver from developed areas degraded by one or more human activities such as road crossings and agricultural areas.

In the late 1700's and early 1800's, most of the European visitors to Oregon were beaver trappers. Killed for their pelts and oil, beaver populations plummeted to low levels (Pollock *et al.*

2003). Since the mid 1800's beaver were also killed to remove them from productive lowlands being converted to agriculture (Pollock *et al*. 2003). Oregon residents can legally remove beavers on their own land without a permit or reporting requirements. We have no data to estimate how many beaver have been removed by landowners. Oregon residents may also harvest beaver for their pelts from someone else's land or public land by acquiring a furtakers license from ODFW. This license requires reporting. The number of these licenses issued has trended downward over the last three decades from 2,052 in 1986 to 1,045 in 2017 (ODFW 2018). The number of beaver harvested has also trended downward, from 5,442 in 1986 to 1,200 in 2017 (ODFW 2018). Considering the reduction of numbers trapped and trend information available in other literature (Naiman *et al*. 1988, Pollock *et al*. 2017), we expect abundance of beaver is at least stable and likely rising.

Beaver removal in Oregon over the last 250 years has resulted in profound changes to stream and wetland conditions. Some of the characteristics most pertinent to salmonids include channel simplification, loss of wetted area, increased water velocity, decreased invertebrate production, and decreased floodplain connection (Naiman *et al*. 1988). While beaver populations have rebounded the last few decades (Pollock *et al*. 2003), the effects of their removal persist throughout the action area.

Anadromous salmonids have been affected by the development and operation of dams in the action area. Dams, without adequate fish passage systems, have extirpated anadromous fish from their pre-development spawning and rearing habitats. Dams and reservoirs, within the currently accessible migratory corridor, have greatly altered the river environment and have affected fish passage. Operations of water storage projects for flooding and irrigation have altered the natural hydrograph of many rivers. Water impoundment and dam operations also affect downstream water quality characteristics, vital components to anadromous fish survival. In recent years, high quality fish passage has been restored through improvements to existing fish passage facilities or through dam removal.

Within the habitat in the action area currently accessible by species considered in this opinion, dams have negatively affected spawning and rearing habitat. Floodplains have been reduced, off-channel habitat features have been eliminated or disconnected from the main channel, and the amount of large wood in mainstem rivers has been greatly reduced. Remaining habitats often are affected by flow fluctuations associated with reservoir water management for power peaking, flood control, irrigation, and other operations.

Development of hydropower and water storage projects within the Columbia River basin has resulted in the inundation of many mainstem spawning and shallow-water rearing areas (loss of spawning gravels and access to spawning and rearing areas); altered water quality (reduced spring turbidity levels), water quantity (seasonal changes in flows and consumptive losses resulting from use of stored water for agricultural, industrial, or municipal purposes), water temperature (including generally warmer minimum winter temperatures and cooler maximum summer temperatures), water velocity (reduced spring flows and increased cross-sectional areas of the river channel), food (alteration of food webs, including the type and availability of prey species), and safe passage (increased mortality rates of migrating juveniles) (Ferguson *et al.* 2005, Williams *et al.* 2005).

ESA-listed fish species within the action area are exposed to high rates of predation during all life stages. Fish, birds, and marine mammals, including harbor seals, sea lions, and killer whales all prey on juvenile and adult salmon and steelhead. Most rivers in Oregon have a diverse assemblage of native and introduced fish species, some of which prey on salmon and steelhead. The primary resident fish predators of salmonids are northern pikeminnow (native), smallmouth bass (introduced), and walleye (introduced). Other predatory resident fish include channel catfish (introduced), Pacific lamprey (native), yellow perch (introduced), largemouth bass (introduced), and bull trout (native). Increased predation by non-native predators has and continues to decrease population abundance and productivity.

Avian predation is another factor limiting salmonid recovery, particularly in the Columbia River Basin. Piscivorous birds congregate near hydroelectric dams and in the estuary near man-made islands and structures. Avian predation has been exacerbated by environmental changes associated with human-caused river development. Water clarity caused by suspended sediments settling in impoundments increases the vulnerability of migrating smolts. Delay in project reservoirs, particularly immediately upstream from the dams, increases smolt exposure to avian predators, and juvenile bypass systems concentrate smolts, creating potential feeding stations for birds. Dredge spoil islands provide habitat for nesting Caspian terns and other piscivorous birds. Caspian terns, double-crested cormorants, glaucous-winged/western gull hybrids, California gulls, and ring-billed gulls are the principal avian predators. As with piscivorous fish, predation by birds has and continues to decrease population abundance and productivity of listed salmonids within the action area.

Water quality throughout most of the action area is degraded to various degrees because of contaminants that are harmful to species considered in this consultation. Aerial deposition, discharges of treated effluents, and stormwater runoff from residential, commercial, industrial, agricultural, recreational, and transportation land uses are all source of these contaminants. For example, 4.7 million pounds of toxic chemicals were discharged into surface waters of the Columbia River Basin and another 91.7 million pounds were discharged in the air and on land in 2011 (USEPA 2011). The 2011 volumes constitute a 39% decrease from 2003 (USEPA 2011). This reduction can be attributed, in part, to significant state, local and private efforts to modernize and strengthen tools available to treat and manage stormwater runoff (USEPA 2009; USEPA 2011).

In a typical year in the U.S., pesticides are applied at a rate of approximately five billion pounds of active ingredients per year (Kiely *et al.* 2004). Therefore, pesticide contamination in the nation's freshwater habitats is ubiquitous and pesticides usually occur in the environment as mixtures. The U.S. Geological Survey's (USGS) National Water-Quality Assessment Program conducted studies and monitoring to build on the baseline assessment established during the 1990s to assess trends of pesticides in basins across the Nation, including the Willamette River basin. More than 90% of the time, water from streams within agricultural, urban, or mixed-land-use watersheds had detections of two or more pesticides or degradates, and about 20% of the time they had detections of ten or more. Fifty-seven percent of 83 agricultural streams had concentrations of at least one pesticide that exceeded one or more aquatic-life benchmarks at least one time during the year (68% of sites sampled during 1993–1994, 43% during 1995–1997, and 50% during 1998–2000) (Gilliom *et al.* 2006). In the Willamette Basin 34 herbicides were detected. Forty-nine pesticides were detected, predominantly in streams draining agricultural land (Rinella and Janet 1998). In the lower Clackamas River basin, Oregon (2000–2005), USGS detected 63 pesticide compounds, including 33 herbicides. High-use herbicides such as glyphosate, triclopyr, 2,4-D, and metolachlor were frequently detected, particularly in the lower-basin tributaries (Carpenter *et al.* 2008).

Johnson *et al.* (2013) found polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT) in juvenile salmon and salmon diet samples from the lower Columbia River and estuary at concentrations above estimated thresholds for effects on growth and survival. The Columbia River between Portland, Oregon, and Longview, Washington, appears to be a significant source of contaminants for juvenile salmon and a region in which salmon are exposed to toxicants associated with urban development and industrial activity. Highest concentrations of PCBs were found in fall Chinook salmon stocks with subyearling life histories, including Snake River populations, which feed and rear in the tidal freshwater and estuarine portions of the river for extended periods. Spring Chinook salmon stocks with yearling life histories that migrate more rapidly through the estuary generally had low PCB concentrations, but high concentrations of DDTs. Pesticides can be toxic to primary producers and macroinvertebrates, thereby limiting salmon and steelhead population recovery through adverse, bottom-up impacts on aquatic food webs (Macneale *et al.* 2010).

The role of stormwater runoff in degrading water quality has been known for years but reducing its volume has been notoriously difficult. This is because runoff is produced everywhere in the developed landscape, the production and delivery of runoff are episodic and difficult to attenuate, and runoff accumulates and transports much of the collective waste of the developed environment (NRC 2009). In most rivers in Oregon, the full spatial distribution and load of contaminants is not well understood. Hydrologically low-energy areas, where fine-grained sediment and associated contaminants settle, are more likely to have high water temperatures, concentrations of nitrogen and phosphorus that may promote algal blooms, and concentrations of aluminum, iron, copper, and lead that exceed ambient water quality criteria for chronic toxicity to aquatic life (Fuhrer *et al.* 1996). Even at extremely low levels, contaminants still make their way into salmon tissues at levels that are likely to have sublethal and synergistic effects on individual Pacific salmon, such as immune toxicity, reproductive toxicity, and growth inhibition (Baldwin *et al.* 2011, Carls and Meador 2009, Hicken *et al.* 2011, Johnson *et al.* 2013), that may be sufficient to reduce their survival and therefore the abundance and productivity of some populations (Baldwin *et al.* 2009, Spromberg and Meador 2006). The adverse effect of contaminants on aquatic life often increases with temperature because elevated temperatures accelerate metabolic processes and thus the penetration and harmful action of toxicants.

The existing highway system within the action area contributes to a poor environmental baseline condition in several significant ways. Many miles of highway that parallel streams have degraded stream bank conditions by armoring the banks with rip rap, degraded floodplain connectivity by adding fill to floodplains, and discharge untreated or marginally treated highway runoff to streams. Culvert and bridge stream crossings have similar effects, and create additional problems for fish when they act as physical or hydraulic barriers that prevent fish access to spawning or rearing habitat, or contribute to adverse stream morphological changes upstream and downstream of the crossing itself.

The environmental baseline includes the anticipated impacts of all Federal actions in the action area that have already undergone formal consultation. The U.S. Army Corps of Engineers (Corps), Bonneville Power Administration (BPA), and Bureau of Reclamation have consulted on large water management actions, such as operation of the Federal Columbia River Power System, the Umatilla Basin Project, and the Deschutes Project. The U.S. Bureau of Indian Affairs (BIA), U.S. Bureau of Land Management (BLM), and the U.S. Forest Service (USFS) have consulted on Federal land management throughout Oregon, including restoration actions, forest management, livestock grazing, and special use permits. The BPA, Corps, NOAA Restoration Center, and U.S. Fish and Wildlife Service have also consulted on large restoration programs within the action area that consist of actions designed to address species limiting factors or make contributions that would aid in species recovery. Restoration actions may have short-term adverse effects, but generally result in long-term improvements to habitat condition and salmonid population abundance, productivity, and spatial structure.

In summary, much of the freshwater water habitat for salmon and steelhead in Oregon has been degraded by one or more human activities. As a result, most salmon and steelhead populations in the state have low abundance and poor productivity. Poor habitat quality is a limiting factor for most populations considered in this opinion.

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. 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 402.17). In our analysis, which describes the effects of the proposed action, we considered 50 CFR 402.17(a) and (b).

2.5.1 Effects on Critical Habitats

Removal of mammals other than beaver

WS-Oregon removal of muskrat, mink, nutria, and river otter will cause little, if any disturbance to the salmon and steelhead critical habitat as those animals' behavior and presence do not positively affect PBFs. Some of these animals may burrow into streambanks to make dens, but those activities are more likely to degrade salmonid habitat than improve it. Thus, their removal is unlikely to adversely impact critical habitat PBFs. WS-Oregon personnel work near, or in the water, which might generate minor amounts of suspended sediment for up to a few hours while traps are being set and removed. However, these effects will be short-term. Therefore, removal of semiaquatic mammals other than beavers is not likely to adversely affect PBFs of critical habitats considered in this opinion.

WS-Oregon may use zinc phosphide concentrate for control of nutria and muskrat by applying it to carrots, in accordance to mixing directions on the pesticide label. These carrots are left in shallow trays for these rodents to consume. Potential effects from zinc phosphide use include changes to invertebrate fauna and exposure to phosphine. Deisch *et al*. (1989) sampled insect populations and found minimal long-term impacts from rodenticide treatments. Those long-term effects detected were mostly due to vegetation growth after the mammals were removed (Deisch 1986). Once in the soil, zinc phosphide breaks down when exposed to moisture, rapidly creating phosphine. Phosphine can be toxic to fish, but it is unlikely to get into the water and is poorly water-soluble unless the water has an acidic pH (which is not common in Oregon). In the soil, phosphine is converted into harmless phosphates and zinc complexes (Sridhara 2016). It may also be released to the atmosphere, but is also quickly broken down. Therefore, use of zinc phosphide is not likely to adversely affect PBFs of critical habitats considered in this opinion.

Removal of beaver

During the analysis period from 2013-2017, WS-Oregon removed beaver from sites with designated critical habitat within three of the twelve ESU/DPSs; UWR Chinook salmon, UWR steelhead, and OC coho salmon (Table 1). These sites were spread across 31 of the 322 HUC5 watersheds. During the analysis period, WS-Oregon removed beaver from 22 sites (approximately 4 per year) from critical habitat for OC coho salmon in one HUC5 watershed (Coquille River HUC# 1710030505). No other HUC5 watershed had more than four removal sites from critical habitat, with 27 of the 31 HUC5 watersheds having only 1 or 2 removals (Figure 2).

The immediate effects of beaver removal on salmon and steelhead critical habitats are minimal. The greatest immediate effect will be minor amounts of suspended sediment created by WS-Oregon personnel operating in streams. The plumes are unlikely to last more than an hour and will be very localized, near where the agent walked in the stream.

Longer lasting effects of beaver removal relate to potential loss of beaver dams. Presence of beaver dams affects the water quantity, water quality, floodplain connectivity, forage, natural cover, and passage PBFs for ESA-listed species within the action area. Pollock *et al*. (2017 and 2003) completed extensive reviews of how beaver dams positively affect hydrology, water quality, and geomorphology of streams. Current information doesn't universally support beaver ponds as wholly beneficial to salmonid critical habitat in every situation but, nevertheless, it is reasonable to conclude that overall, the published science applicable to the action area documents a predominantly positive effect of beaver dams related to juvenile salmonid rearing habitat by increasing suitable habitat area, habitat quality, and habitat complexity (see Kemp *et al*. 2012). In this analysis, we assume all beaver dams positively affect salmonid habitat (except passage) because it allows us to analyze the worst case scenario and give the benefit of doubt to the species.

Below, we summarize how beaver dams can enhance and maintain critical habitat PBFs. We also describe how the proposed action will affect PBFs. The longevity of beaver ponds varies given many environmental conditions. Winter high water flows may breach the dam annually or they may persist for years. One factor in dam longevity is having beavers at the site to maintain it. Because WS-Oregon will remove beavers, as a result of WS-Oregon's activities, some beaver dams will degrade and be lost at a rate faster than would otherwise naturally occur. Also, breached beaver dams may be rebuilt if beavers are on site. This may not happen if WS-Oregon has removed beavers from the area.

It is also reasonably certain some landowners will remove beaver dams after WS-Oregon removes beavers from their site since the conflict is usually due to the dams being in place, not the beavers themselves. Unfortunately, we do not have data on the increased probability a dam will be lost once beavers are removed, how much faster dams will be lost without beaver to maintain them, or how long it will take for new beaver to move into the area and rebuild. Therefore, for this analysis we assume when WS-Oregon removes beaver from a site, it results in loss of a beaver dam and associated pond. This constitutes the worst case scenario and gives the benefit of doubt to the species. The effects on PBFs described below apply to all salmon and steelhead considered in this opinion.

Water Quantity. By impounding water, beaver dams hold water within the stream reach for longer periods of time, increasing the amount of critical habitat available (Pollock *et al*. 2017). Beaver dam-impounded water recharges and elevates the groundwater table (Lowry 1993, Pollock *et al.* 2003). This water retention decreases flood flows and increases base flows (reviewed in Pollock *et al*. 2003, Ponce and Lindquist 1990), potentially improving migration conditions, though we are unaware of empirical data to support this hypothesis. Higher summer base flows increase juvenile rearing habitat when it is shortest in supply. Water quantity is particularly important in the face of climate change as increased drought and reduced snow pack in the action area is expected. Water storage from beaver impoundments may be an effective tool to help mitigate the climate change related reductions in water resources (Rosemond and Anderson 2003). Because beaver dams attenuate flood peaks and dissipate flood energy (Pollock *et al*. 2017), they likely reduce redd scouring.

Water Quality. Beaver dams improve the water quality of streams by reducing suspended sediments in the water column, moderating stream temperatures, improving nutrient cycling, and removing and storing contaminants (Pollock *et al*. 2017). Because beaver dams reduce flow velocities and dissipate stream energy, they promote sediment deposition and channel aggradation (Naiman *et al*. 1986). Beaver dams can influence sediment transport rates in an entire watershed and act as long-term sinks for both suspended and bedload sediments (Green and Westbrook 2009).

Cold pockets of water occur downstream of beaver dams, presumably from the upwelling of groundwater and an increase in hyporheic exchange caused by their existence (Pollock *et al.* 2007, White 1990). Weber *et al.* (2017) reported high densities of beaver dams reduced maximum summer stream temperatures. Such pockets or reaches of cooler water could be important refuges for salmonids when summer water temperatures are high (Wathen *et al.* 2018). This is particularly important because maximum summer temperatures are often the single most important factor limiting the distribution and presence of salmonids (McRae and Edwards 1994, Wenger *et al*. 2011) and climate change models predict continued warming in the action area.

Floodplain Connectivity. Beaver dams can increase floodplain connectivity by raising the water level onto the floodplain. This results in reconnecting or forming new side channels, creating off-channel salmonid habitat and increasing the amount of riparian area (Bouwes *et al.* 2016, Pollock *et al.* 2017, Westbrook *et al.* 2006). Floodplain connectivity helps increase the quantity and quality of salmonid rearing habitat. Beaver recolonization and construction of beaver dams, along with the installation of man-made beaver analog structures, in the incised channel of

Bridge Creek, Oregon, raised water levels at a rate of 3.9 inches/year (Pollock *et al.* 2007). Beechie *et al.* (2008) estimated that, with beaver recolonization and 3.2 dams per mile of stream on average, the time required for an incised channel to aggrade to the level of its historical floodplain could decrease by 17–33%, compared to sites without beavers.

Forage. When beavers modify streams with dams, they create habitat for many aquatic insect populations by increasing the input and storage of organic material and sediment (Collen and Gibson 2000) and increasing primary productivity. Primary production increases secondary production, including micro- and macroinvertebrates that form the base of the food web that juvenile salmon and steelhead rely on when rearing and overwintering in beaver ponds (Pollock *et al.* 2017). Larger riparian zones due to beaver dams contribute more allochthonous material, including terrestrial insects, which is important salmonid forage.

Natural Cover. Beaver ponds provide channel complexity and many forms of natural cover for juvenile salmonids including deep water, woody material, overhead cover from riparian vegetation, and, potentially, side channels. Beaver ponds have slow current velocities and large edge-to-surface-area ratios, conditions that provide extensive natural cover to fish and are productive for vegetation growth (reviewed in Pollock *et al.* 2017). In winter, maximum pool depth was positively correlated with juvenile coho salmon density in dammed pools (which included beaver ponds) along with scour and trench pools (Nickelson *et al.* 1992). Nickelson *et al.* (1992) hypothesized that in these pool types, depth may be a factor that reduces current velocity and turbulence.

Passage. Salmonids cross beaver dams by swimming through or over the dam where water is flowing, or by swimming around the dam using side channels (Pollock *et al*. 2017). We can also infer their ability to pass beaver dams from observations of spawning adult salmon and rearing juvenile salmon in stream reaches above beaver dams (reviews in Pollock *et al.* 2017).

However, there are instances where beaver dams pose problems for fish migration (Collen and Gibson 2000). While we found little other data or literature documenting this effect, we are reasonably certain culverts blocked by beaver dams can hinder upstream fish passage. We arrive at this conclusion after visiting several culvert locations within the action area plugged by beaver dams. In our experience, culverts allow beavers to build taller structures that are sturdier and have less leakage than beaver dams at non-culvert sites. These characteristics make swimming through or over the dam difficult for salmonids. Furthermore, roads associated with the culverts typically eliminate the potential for side channels or floodplain flow that would allow fish to swim around the dam. In these cases, removal of the dam has beneficial effects on fish passage in addition to the adverse effects described above.

Non-lethal control of beaver

During the removals discussed above, when WS-Oregon has authorizations to relocate and release beavers back into streams, they will live trap beaver. When successful (for purposes of this opinion, we define successful relocation as presence of beaver at the relocation site and maintaining a dam one year after release), relocated beaver provide functionally equivalent ecological and biological benefits at the relocation site that were lost at the removal site, including for water quantity, water quality, floodplain connectivity, forage, and natural cover.

However, relocation has a poor track record of success. Re-establishing colonies by relocating beaver to areas where they do not currently exist has been challenging, with high mortality rates for the beaver (McKinstry and Anderson 2002). Radio-tagged beaver released into nine sites in coastal Oregon experienced a survival rate of 47% (Petro 2013). In the Yakima River drainage (Washington), 161 beaver were relocated with a 35% success rate (defined as the animals staying and building dams at the release site).[6] Though, some animals were detected in other reaches where they may provide beneficial habitat. In response to growing interest in relocating "nuisance" beavers, ODFW published *Requirements for Relocation of Beaver in* Oregon in December 2017. The purpose of which is to improve the chances relocated beaver will survive and colonize the new location. When we look at the few relocations attempted during the analysis period, and the low probability of success, we cannot be assured that any successful relocation will occur.

Other non-lethal methods of beaver control allow most if not all of the benefits to PBFs from beaver dams to remain. Wrapping trees with wire mesh, coating their trunks with sand-infused paint, or other fencing and devices to keep beavers from unwanted chewing of trees will have minimal or no effect on PBFs as beavers are left in place to maintain their dams. Pond levelers (described in Pollock *et al*. 2017) maintain lower water levels above the dam, but keep the beavers and dams in place to provide benefits to PBFs as discussed above, but to a lesser degree. Culvert-protective fences (usually described as beaver deceivers) are constructed in various manners, but all work on the premise of keeping beavers from the culvert and giving them an alternative dam-building location. Beaver deceivers keep beavers in place to build and maintain dams, which provide benefits to PBFs as discussed above. However, fish passage at beaver deceivers and dams with pond levelers have not been well studied and is reasonably likely poorer than fish passage at a natural beaver dam.

During the 5-year period of 2013-2017, WS-Oregon relocated five beavers and did not install any pond levelers or deceivers. Given the growing enthusiasm for non-lethal control of beaver, it is reasonably likely WS-Oregon will implement increasing numbers of these actions in the future.

Summary of effects on critical habitats

Removal of mammals other than beaver will result in minimal if any effect on critical habitats. Under the proposed action, we expect WS-Oregon to remove beavers from up to 66 sites on streams with ESA-designated critical habitats over any 5-year period with similar but not exact distribution as the 5-year analysis period. Once removed, beavers will not maintain existing dams or build new ones. As a result, the benefits to PBFs provided by beaver ponds will degrade and eventually be lost. Where beaver dams plug culverts, loss of the dam will improve fish passage. Installing pond levelers and deceivers may decrease fish passage and will reduce the pond's benefits to PBFs, but not eliminate them. Other non-lethal methods (except relocation) leaving beaver in place will have minimal or no effect on PBFs as they will maintain their dams.

[6] http://midcolumbiafisheries.org/restoration/beaver-restoration/beaver-reintroduction/, accessed March 29, 2019.

Beaver removal sites will be dispersed geographically across the action area. With the exception of the Coquille River HUC5, we expect WS-Oregon will remove beaver from four or less sites on critical habitat streams within a 5-year period in any HUC5. The average HUC5 watershed is 227 square miles. Critical habitat PBFs will be adversely affected at a site level, but because of the spatial and temporal distributions, the proposed action is unlikely to affect the function of any PBFs for any ESU/DPS considered in this opinion at the watershed scale.

For the 174 square mile Coquille River HUC5, we expect WS-Oregon will have as many as 22 removal sites in any 5-year period. This HUC5 has flat topography and wet climate giving rise to a large number of beaver pond locations. Almost all of WS-Oregon's removals are from the extensive low-lying road network or agricultural infrastructure in this HUC5.[7] OC coho salmon critical habitat is the only listed salmonid critical habitat found within this HUC5.

Several researchers reported average pond size behind beaver dams. Nickelson *et al.* (1992) found an average beaver pond area of 4,844 ft^2 for Oregon coastal river basins. Demmer and Beschta (2008) reported an average pond size of 1,292 ft^2 on Bridge Creek in Eastern Oregon. In a different eastern Oregon stream, McComb *et al*. (1990) found an average pond area of 1,798 ft^2. For our analysis, we use an average of these three values (2,645 ft^2) as an estimate of the potential loss of rearing habitat at each beaver removal site. Given 22 removal sites, approximately 1.34 acres of beaver pond rearing habitat will be lost in the 174 square mile Coquille River HUC5 over each 5-year period (approximately 0.001% of this HUC5).

Because WS-Oregon's proposed action will result in only a small loss in acreage of beaver pond habitat within the Coquille River HUC5 and a very small portion of rearing habitat within HUC5, the proposed action will not affect critical habitat PBFs for OC coho salmon at the watershed scale.

2.5.2 Effects on Species

Removal of mammals other than beaver

WS-Oregon removal of muskrat, mink, nutria, and river otter is unlikely to kill or injure individual fish. Personnel working near or in the water may temporarily displace some fish. Personnel might also generate minor amounts of suspended sediment during management activities. Both of these effects will be short-term and not likely to injure, harm, or reduce the fitness of any individual salmon or steelhead. Phosphine used for nutria control can be toxic to fish, but it is unlikely to get into the water and is poorly water-soluble unless the water has an acidic pH (which is not common in Oregon[8]).

[7] Telephone conversation between Kevin Christensen (WS) and Chuck Wheeler (NMFS), April 17, 2019, discussing the number of removal sites in the Coquille River watershed.
[8] A query of the USGS current conditions website (https://waterdata.usgs.gov/or/nwis/current) found 24 stations in Oregon monitor pH. The average pH of these streams was 7.7. Only 1 stream in Oregon registered an acidic pH, and it was only lightly acidic (6.8).

Removal of beaver

As explained in the effects to critical habitat section above, for the purposes of our analysis we have to make assumptions about the value of beaver ponds and the longevity of beaver dams after WS-Oregon removes the beaver. We assume all beaver dams positively affect salmonid habitat (except passage). We also assume when WS-Oregon removes beaver from a site, it results in loss of a beaver dam and associated pond. These assumptions allow us to analyze the worst case scenario and give the benefit of doubt to the species.

Pacific Northwest salmon and steelhead evolved with beaver dams and adapted to their presence. Pollock *et al.* (2017) and Pollock *et al*. (2003) completed extensive reviews of how beaver dams affect the hydrology, water quality, and geomorphology of streams. Beaver dams can play a critical role in replenishing alluvial aquifers by trapping and storing water, redirecting surface water onto adjacent floodplains, and forcing water into the streambed and banks. Beaver dams slow stream flows, holding the water within the stream reach for longer periods, which can increase base flows. Beaver dams create surface pools and ponds, transforming moving-water habitats to a combination of moving- and slow-water habitat and lead to an expansion of riparian and wetland habitats along streams. Beaver ponds add habitat complexity, including variation in temperatures, depths, and velocities, as well as potential prey diversity (McDowell and Naiman 1986, Wathen *et al.* 2018, Weber *et al*. 2017). All of these effects benefit salmon and steelhead survival and abundance. Recent studies in the Lower Klamath, Middle Klamath and Shasta sub-basins confirm that beaver ponds provide high quality summer and winter rearing habitat for coho salmon (Chesney *et al*. 2009, Silloway 2010).

Current information does not universally support beaver ponds as wholly beneficial to salmonids in every situation. Malison *et al*. (2015) found higher densities of Chinook salmon juveniles in beaver-free spring brooks than in early-successional beaver ponds on the Kwethluk River, Alaska, although the total biomass per square foot in beaver ponds was greater because the juveniles were significantly larger. Malison *et al.* (2016) estimated that if beavers were not present on the Kwethluk River floodplain, habitats would be fully interconnected and theoretically could produce three times the number of salmon compared to the existing condition with beaver dams present. Murphy *et al*. (1989) found that Chinook salmon were virtually absent from beaver ponds and upland sloughs in the Taku River, Alaska. Given that the above studies were on very large Alaskan rivers with high floodplain connections, the results may not be applicable to many river systems in Oregon. Collen and Gibson (2000) report that beaver dams built at culverts could prevent fish passage by plugging the culvert.

It is reasonable to conclude that overall, the best available information, including published science, applicable to the action area documents a predominantly positive effect of beaver dams on salmonids. Most of the benefits come from increasing suitable juvenile rearing habitat area and adding habitat complexity to streams. Other benefits include decreased summer stream temperatures, increased base flows, and decreased suspended sediment.

Benefits of beaver ponds to species considered in this opinion are also well documented in applicable recovery plans. The Oregon Coast coho salmon recovery plan (NMFS 2016a) lists beaver ponds as a key habitat condition for creating complex overwintering habitat, which is the most limiting factor for the species. It discusses repeatedly the dependence of this species on beaver pond habitats. One of the four strategies to improve habitat at the ESU level is: "Ensure long-term ecosystem functions and high quality habitat by reducing habitat-related threats and encouraging formation of beaver dams and beaver dam analogues."

The SONCC coho salmon recovery plan found beaver ponds provide high quality winter and summer rearing habitat for coho salmon (Reeves *et al.* 1989, Pollock *et al.* 2004), and the effect of decreased beaver abundance on coho salmon populations was likely very significant. Increasing beaver abundance is a recovery action to increase channel complexity. The Lower Columbia River recovery plan (NMFS 2013) lists beaver ponds as one of the key habitats for active rearing coho salmon, and fall and spring Chinook salmon. One of the plan's recovery strategy elements is tributary habitat restoration (particularly overwintering habitat; NMFS 2013). Thus, beaver pond habitat is not specifically called for, but the importance of it is implied.

The recovery plan for UWR Chinook salmon and steelhead (NMFS 2011) acknowledges the importance of beaver dams to these species with several recovery actions. These actions include providing incentives to landowners to allow beaver to remain on their lands and providing education and outreach materials on the benefit of beaver dams to juvenile rearing habitat. The MCR steelhead recovery plan (NMFS 2009) discusses the extensive beaver activity creating diverse instream habitats, with deep pools and strong connections to floodplains. It includes beaver dams in the definition of natural cover for PBFs important to juvenile survival.

<u>Effects on Lower Columbia River, Upper Willamette River, Snake River fall-run, and Snake River spring/summer-run Chinook salmon</u>

Traditionally, Chinook salmon are often referred to as having two main life history types: those that migrate to the ocean during their first spring and summer after hatching ("ocean type"), and those that rear for a year in freshwater before emigrating to the ocean ("stream type"). However, the traditional model describing Chinook salmon life histories as simply "ocean-type" or "stream-type" is being challenged with descriptions that more fully accommodate the diversity of life-history pathways (Bourret *et al.* 2016). For this analysis, we consider the numerous life-history variations and conclude Chinook salmon juveniles will likely be present and exposed to the effects when WS-Oregon removes beavers.

Juvenile Chinook salmon have been documented using habitat created or enhanced by beaver ponds. In the Fish Creek basin, Oregon, on the west slope of the Cascade Range, Everest *et al*. (1986) found Chinook salmon juveniles in beaver ponds in low densities (0.004 fish/ft^2). However, they noted that Age-0 Chinook salmon are not abundant in the Fish Creek system because most fry emigrate to the Clackamas River soon after emergence. Hood (2012) found beaver ponds in the tidal marsh of the Skagit River significantly increased habitat quantity and quality for Chinook salmon, concluding that restoration efforts should be focused on this tidal shrub habitat. For this analysis, we have no reason to doubt that the potential for Chinook salmon juveniles to rear is enhanced by beaver pond habitat.

To predict the effect of losing beaver pond habitat on Chinook salmon, we estimated juvenile density in beaver ponds and multiplied by the average size of beaver ponds. The only empirical data we found for juvenile Chinook salmon densities in beaver ponds in Oregon is 0.001 fish/ft^2 (Everest *et al.* 1986). There is also limited information outside of Oregon. Swales and Levings (1989) found overwintering densities of 0.0007-0.012 Chinook salmon juveniles/ft^2 in beaver ponds of streams in British Columbia. Therefore, we assume average densities of 0.0037 Chinook salmon juveniles/ft^2 of beaver pond habitat (which is the average of the two studies) for our analysis.

We also found a study by Hood (2012), but did not use it for our estimate. That study found Chinook salmon juvenile densities of 0.02 fish/ft^2 in the Skagit estuary in Washington. However, the study is not pertinent to our analysis. Densities of Chinook salmon juveniles is higher in estuaries (because of their high expression of ocean-type life history) and WS-Oregon is unlikely to remove beaver from estuarine areas.

Using the estimated average juvenile density (0.0037 fish/ft^2) and the estimated average pond size (2,645 ft^2, calculated in section 2.5.1), we calculate an average beaver pond within the action area will support 10 Chinook salmon juveniles. If beaver are removed, existing habitat features will degrade, or the development of such features will cease because the beavers will not be there to maintain their existing dams or build new ones (Pollock *et al*. 2017). The reduction in rearing habitat will force juvenile Chinook salmon to move elsewhere to find adequate forage and cover. Displaced fish will expend more energy searching for food or cover, resulting in slower growth and lower fitness. These individuals will be more susceptible to predation and have decreased chances for survival. Thus, some juvenile Chinook salmon displaced from beaver ponds within the action area will experience harm and potential death due to the indirect effects of beaver removal.

We cannot accurately predict how many juveniles will be injured or killed per removal site, but it will not be all 10, because the remaining stream channel will still provide some rearing habitat.

The proposed action has both positive and negative effects on Chinook salmon adult and juvenile passage. In areas where beaver dams plug culverts, loss of the dam following beaver removal will improve fish passage. However, installation of pond levelers and deceivers may decrease upstream fish passage, causing delays or blockages, which may result in reduced spawning success or juvenile fitness.

Installation of pond levelers and deceivers lowers the pond surface elevation, thereby reducing the benefits to juvenile rearing habitat. Because these devices allow continued existence of the pond, many of the benefits also continue.

Based on the geographic dispersal of past beaver removal locations, we believe it is highly unlikely that more than four removal sites will occur on streams with listed Chinook salmon in any HUC5 watershed within a 5-year period. WS-Oregon removed no beaver from streams in the range of LCR, SR fall-run, or SR spring/summer-run Chinook salmon in the 5-year analysis period (Table 1). We find it unlikely that WS-Oregon will remove beavers from more than a few sites with presence of individuals of these ESUs in any 5-year period. During the analysis period, WS-Oregon removed beaver from four total sites on streams containing UWR Chinook salmon. These removals occurred in four different HUC5s. Because of the proposed few number of beaver removal sites and their spatial and temporal distribution, combined with the small number of Chinook salmon affected per site, the proposed action is unlikely to have an appreciable effect at the population scale of any Chinook salmon ESU considered in this opinion.

Effects on Columbia River chum salmon

Columbia River chum salmon typically spawn in low-gradient, low-elevation reaches of the Columbia River mainstem, its side channels, and in a few larger tributaries (NMFS 2013). Chum salmon fry emigrate downstream soon after emergence, which typically occurs from March through May (NMFS 2013). The fry do not typically have substantial freshwater rearing time (Lower Columbia Fish Recovery Board 2010).

CR chum salmon are unlikely to rear in beaver dam ponds. Although chum salmon are strong swimmers, they rarely pass river blockages and waterfalls that pose no hindrance to other salmon or steelhead (ODFW 2010). Even if adults passed upstream of a beaver dam and spawned, fry move to estuary quickly and would not reside in the pond for long.

However, WS-Oregon's beaver removal activities are likely to cause harm to CR chum salmon by significantly impairing their essential behavioral patterns for spawning. Chum salmon typically spawn in upwelling areas with gravels free of sedimentation (NMFS 2013). Beaver dams sequester sediment behind the dams keeping it from downstream areas (Green and Westbrook 2009, Naiman *et al*. 1986, Pollock *et al*. 2007), and cause upwelling downstream of the dam (Pollock *et al*. 2007, White 1990). Thus, when WS-Oregon removes beaver from streams where chum salmon spawn, the subsequent loss of beaver dams may reduce spawning success causing them harm.

Based on the geographic dispersal of past beaver removal locations, we believe it is highly unlikely that more than four removal sites will occur on streams with listed chum salmon in any HUC5 watershed within a 5-year period. WS-Oregon removed no beaver from streams in the range of CR chum salmon in the 5-year analysis period (Table 1). We find it unlikely that WS-Oregon removes beavers from more than a few sites in any 5-year period affecting chum salmon spawning. Because of the proposed few number of beaver removals and the limited affect beaver dams have on chum salmon, the proposed action is unlikely to have an appreciable effect at the population scale of the CR chum salmon ESU.

Effects on Lower Columbia River, Southern Oregon/Northern California Coast, and Oregon Coast coho salmon

Coho salmon are widely distributed throughout accessible streams, large and small, on the Oregon Coast and lower Columbia River. Adult coho salmon migrate into relatively small tributaries with low to moderate gradient stream reaches to spawn (NMFS 2016a). The dominant life-history pattern is for juvenile coho salmon to feed and rear in freshwater for a year before migrating to the ocean. During their year in freshwater, coho salmon juveniles may move upstream or downstream seeking habitat optimal for growth and survival. Typical juvenile rearing habitat consists of slow moving, complex pool habitat commonly found within small, heavily forested tributary streams (Moyle 2002, Quinn 2005).

During summer, juvenile coho salmon prefer deep pools and areas with complex cover and large wood (Nickelson *et al*. 1992, Brown *et al*. 1994). In the winter, juvenile coho salmon avoid being washed downstream with high flows by using flow refugia, including deep pools, complex stream channels, and large wood (Tripp and McCart 1983, Skeesick 1970, Narver 1978, Quinn and Peterson 1996).

Beaver ponds provide high quality winter and summer rearing habitat for coho salmon (Reeves *et al*. 1989, Pollock *et al*. 2004). Everest *et al*. (1986) reported that beaver ponds were the preferred habitat of juvenile coho salmon in the Fish Creek Basin, Oregon. Some researchers have documented beaver ponds support the highest densities of coho salmon (Murphy *et al*. 1989, Nickelson *et al*. 1992), while others have seen mixed results (Leidholt-Bruner *et al*. 1992, Malison *et al*. 2015). All of these studies found that beaver dams increase coho salmon carrying capacity due to the increase in total habitat. For instance, Leidholt-Bruner *et al*. (1992) noted that coho salmon density did not differ between beaver ponds and non-beaver pools, but beaver pools added 7% and 14% more total habitat in two Oregon coastal streams.

Beaver ponds not only increase carrying capacity, but coho salmon in beaver ponds have over-winter survival rates as much as twice that of their instream counterparts (Bustard and Narver 1975, Murphy *et al*. 1989). Coho salmon emigrating from beaver ponds on average have higher growth rates and are larger than those from free-flowing streams (Swales and Levings 1989). Because size is important determinant of survival (Bilton *et al*. 1982), these studies suggest that coho salmon raised in beaver ponds constitute a disproportionate percentage of adult returners.

We found a few sources of data for juvenile coho salmon densities in beaver ponds within Oregon. In Oregon coastal streams, Nickelson *et al*. (1992) reported a density of 0.12 fish/ft^2, while Leidholt-Bruner *et al*. (1992) found densities of 0.03 fish/ft^2. In a tributary in the Columbia River Basin, Everest *et al*. (1986) found densities of 0.13 fish/ft^2. For our analysis, we assume average densities of 0.09 coho salmon juveniles/ft^2 of beaver pond habitat (which is the average of the three studies).

Using the estimated average pond size from above (2,645 ft^2), we calculate the average beaver pond can support 238 coho salmon juveniles. If beaver are removed, existing habitat features will degrade, or the development of such features will cease because the beavers will not be there to maintain their existing dams or build new ones (Pollock *et al*. 2017). The reduction in rearing habitat will force juvenile coho salmon to move elsewhere to find adequate forage and cover. Displaced fish will expend more energy searching for food or cover, resulting in slower growth and lower fitness. These individuals will be more susceptible to predation and have decreased chances for survival. Thus, some juvenile coho salmon displaced from beaver ponds will experience harm and potential death due to the indirect effects of beaver removal.

The number of juveniles actually harmed per removal site will not be all 238, because the remaining stream channel will still provide some rearing and other individuals will successfully rear elsewhere. Taking this into consideration, we expect the number of individuals harmed from

WS-Oregon's activities is likely to be about 10% of those that resided in the pond (approximately 24).

The proposed action has both positive and negative effects on coho salmon adult and juvenile passage. In areas where beaver dams plug culverts, loss of the dam following beaver removal will improve fish passage. However, installation of pond levelers and deceivers may decrease upstream fish passage, causing delays or blockages, which may result in reduced spawning success or juvenile fitness. Installation of pond levelers and deceivers lowers the pond surface elevation, thereby reducing the benefits to juvenile rearing habitat. Because these devices allow continued existence of the pond, many of the benefits also continue.

Based on the geographic dispersal of past beaver removal locations, we believe it is highly unlikely that more than four removal sites will occur on streams with listed coho salmon in any HUC5 watershed within a 5-year period, with the exception of the Coquille HUC5. WS-Oregon removed no beaver from streams in the range of LCR coho salmon or SONCC coho salmon in the 5-year analysis period (Table 1). We find it unlikely that WS-Oregon will remove beavers from more than a few sites with presence of individuals of these two ESUs in any 5-year period. Because of the proposed few number of beaver removals and their spatial and temporal distribution, combined with the small number of coho salmon affected per site (approximately 24), the proposed action is unlikely to have a measurable effect on any population of LCR coho salmon or SONCC coho salmon.

For the OC coho salmon ESU, WS-Oregon removed beaver from 62 sites on streams where they are present during the 5-year analysis period, spread across 27 of the 78 HUC5s where this ESU is found (See Table 1). The greatest effect occurred in the Coquille River population. Of the 62 sites where beavers were removed, 31 occurred in the five HUC5s of the Coquille River population and 22 removals occurred in the Coquille River HUC5.

Only a portion of coho salmon juveniles residing in the beaver pond are likely to actually be harmed by the proposed action as the remaining stream channel will still provide some rearing habitat, and other juveniles will successfully rear elsewhere. We expect the number of individuals harmed from WS-Oregon's activities is likely to be about 10% of those that resided in the pond (approximately 24). Using this number of juvenile coho salmon harmed per beaver pond (24), the average number of removal sites per year (31/5 = 6.2), the 15-year average adult per smolt ratio for coastal coho salmon in Oregon (0.026, Peterson *et al*. 2018), and the 15-year annual average of natural-origin adults returning to the Coquille River (18,746, ODFW 2019), we expect the proposed action to affect approximately 0.0002% of the Coquille population per year (approximately 3.9 adult equivalents). This calculation likely overestimates impacts on OC coho salmon because it uses smolt to adult survival and only a portion of juveniles survive to smolt stage. Due mostly to the lower number of beaver removals,[9] the percentage of the population affected is substantially lower in every other OC coho salmon population. Furthermore, because these percentages are so low, the proposed action is unlikely to change population level characteristics such as diversity, spatial structure, abundance, or productivity for

[9] No other population had more than 6 removal sites from streams with OC coho salmon present during the 5-year analysis period.

any population within the OC coho salmon ESU and therefore the proposed action is unlikely to have an appreciable effect at the population scale.

Effects on Lower Columbia River, Upper Willamette River, Middle Columbia River, and Snake River steelhead

Steelhead have the greatest diversity in life history strategies of all Pacific salmonids (Quinn 2005). They may spend up to five years in freshwater before smolting and emigrating to the ocean (Copeland *et al*. 2017). Traditionally, steelhead are known to prefer shallow, slow-moving water as fry and shift towards deeper habitats with greater velocities as they age (Everest and Chapman 1972). However, much research has shown steelhead have diverse movement patterns to find preferential rearing habitat and optimize survival and growth (Myrvold and Kennedy 2016, Wathen *et al*. 2018).

Researchers have found steelhead benefit from beaver pond habitat. Bouwes *et al.* (2016) built artificial beaver dams (beaver dam analogs, BDAs) in reaches of Bridge Creek, Oregon. The BDAs complemented existing beaver dams and encouraged additional beaver activity. Bouwes *et al*. (2016) found steelhead abundance, survival, and production increased dramatically in beaver pond habitat compared to a control stream. Wathen *et al*. (2018) found the density of juvenile steelhead in Bridge Creek was almost three times higher in beaver pond habitat than habitat unaffected by beaver.

In contrast to the above research, Everest *et al*. (1986) found beaver ponds had the lowest juvenile steelhead densities of the six habitat types they investigated in Fish Creek, Oregon. This discrepancy is likely due to Fish Creek being cohabited by coho salmon who show a strong preference for beaver pond habitat. Steelhead likely avoid beaver ponds in Fish Creek due to increased competition with coho salmon, while in Bridge Creek steelhead may have taken advantage of ponded areas because coho salmon are not present.

The best empirical data for steelhead densities in beaver ponds in Oregon comes from the two streams in the above research. Steelhead density in Bridge Creek was 0.067 fish/ft2 (Wathen *et al*. 2018). Steelhead density in Fish Creek was 0.015fish/ft^2 (Everest *et al.* (1986). Because of the difference between these numbers and the likely influence from presence of coho salmon, we use both in predicting the densities of steelhead in streams across Oregon. We use the Fish Creek density for LCR steelhead and UWR steelhead due to the likely presence of coho salmon. We use the Bridge Creek density for MCR steelhead and SR steelhead because presence of coho salmon is less likely.

Using the estimated average juvenile densities (0.067 and 0.015 fish/ft^2) and the estimated average pond size (2,645 ft^2), we calculate an average beaver pond can support 177 steelhead in the MCR and SR steelhead DPSs and 40 steelhead in the LCR and UWR steelhead DPSs. If beaver are removed, existing habitat features will degrade, or the development of such features will cease because the beavers will not be there to maintain their existing dams or build new ones (Pollock *et al*. 2017). The reduction in rearing habitat will force juvenile steelhead to move elsewhere to find adequate forage and cover. Displaced fish will expend more energy searching for food or cover, resulting in slower growth and lower fitness. These individuals will be more susceptible to predation and have decreased chances for survival. Thus, some juvenile steelhead displaced from beaver ponds will experience harm and potential death due to the indirect effects of beaver removal.

We cannot accurately predict how many juveniles will be injured or killed per removal site, but it will not be all 177 or 40, because the remaining stream channels will still provide some rearing.

The proposed action has both positive and negative effects on steelhead adult and juvenile passage. In areas where beaver dams plug culverts, loss of the dam following beaver removal will improve fish passage. However, installation of pond levelers and deceivers may decrease upstream fish passage, causing delays or blockages, which may result in reduced spawning success or juvenile fitness.

Installation of pond levelers and deceivers lowers the pond surface elevation, thereby reducing the benefits to juvenile rearing habitat. Because these devices allow continued existence of the pond, many of the benefits also continue.

Based on the geographic dispersal of past beaver removal locations, we believe it is highly unlikely that more than four removal sites will occur on streams with listed steelhead within a 5-year period in any HUC5. WS-Oregon removed no beaver from streams in the range of LCR, MCR, or SR steelhead in the 5-year analysis period (Table 1). We find it unlikely that WS-Oregon removes beavers from more than a few sites containing individuals of any of these DPSs in any 5-year period. During the analysis period, WS-Oregon removed beaver from four sites on streams where UWR steelhead were present. These removals occurred in four different HUC5s. Because of the proposed few number of beaver removals and their spatial and temporal distribution, combined with the small number of steelhead affected per site, the proposed action is unlikely to have an appreciable effect at the population scale of any steelhead DPS.

Summary of effects on species

Removal of mammals other than beaver will result in minimal if any effect on any species considered in this opinion. Under the proposed action, we expect WS-Oregon to remove beavers from up to 66 sites on streams with ESA-listed species present over any 5-year period with similar but not exact distribution as the 5-year analysis period. Removed beavers will not maintain existing dams or build new ones. As a result, the benefits to species provided by those dams will degrade and be lost and the carrying capacity of streams reduced. Individuals of each ESU/DPS are likely to be displaced from beaver ponds where beavers are removed and likely to experience harm and potential death. The proposed action has both positive and negative effects on adult and juvenile passage. Non-lethal management methods, such as pond levelers or beaver deceivers, have negative effects, though much less than removing beavers. Considering the number of beaver removal sites, their expected geographical spread, the number of individuals affected in any salmon or steelhead population, and the potential improved fish passage at some culvert sites, overall the proposed action will not appreciably negatively affect Chinook salmon, chum salmon, coho salmon, or steelhead abundance, productivity, spatial structure or diversity of any ESU or DPS considered in this opinion.

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 and 402.17(a)). 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 in the environmental baseline (Section 2.4).

The contribution of non-Federal activities to the current condition of ESA-listed species and designated critical habitats within the action area was described in the Status of the Species and Critical Habitats and Environmental Baseline sections, above. Among those activities were agriculture, forest management, mining, road construction, urbanization, water development, and river restoration. Those actions were driven by a combination of economic conditions that characterized traditional natural resource-based industries, general resource demands associated with settlement of local and regional population centers, and the efforts of social groups dedicated to river restoration and use of natural amenities, such as cultural inspiration and recreational experiences.

Beaver removals by private parties will continue into the future. Oregon residents can legally remove beavers on their own land without a permit or reporting requirements. We have no data to estimate to what extent this occurs, but it is likely to remain stable over time with effects at levels similar to the past. To remove beaver from someone else's land or public land, one must acquire a furtakers license from ODFW. This license requires reporting. The number of these licenses issued has trended downward in the last decade from 1,377 in 2008 to 1,045 in 2017 (ODFW 2018). The number of beaver harvested has also trended downward, from 2,412 in 2008 to 1,200 in 2017 (ODFW 2018). This trend is likely due to the declining price of pelts (ODFW 2018), but could also be influenced by the increased environmental awareness of the benefits of beaver. We have no information leading us to expect these trends will stabilize or reverse. Therefore, the future effects of private party beaver harvesting are likely to decline over time.

Resource-based industries caused many long-lasting environmental changes that harmed ESA-listed species and their critical habitats, such as state-wide loss or degradation of stream channel morphology, spawning substrates, instream roughness and cover, estuarine rearing habitats, wetlands, riparian areas, water quality (*e.g.*, temperature, sediment, dissolved oxygen, contaminants), fish passage, and habitat refugia. Those changes reduce 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. However, the declining level of resource-based industrial activity and rapidly rising industry standards for resource protection are likely to reduce the intensity and severity of those impacts into the future.

The economic and environmental significance of the natural resource-based economy is currently declining in absolute terms and relative to a newer economy based on mixed manufacturing and marketing with an emphasis on high technology (Brown 2011). Nonetheless, resource-based industries are likely to continue to have an influence on environmental conditions within the action area for the indefinite future.

While natural resource extraction within the Pacific Northwest may be declining, general resource demands are increasing with growth in the size and standard of living of the local and regional human population (Metro 2010, Metro 2011). Population growth is a good proxy for multiple, dispersed activities and provides the best estimate of general resource demands because as local human populations grow, so does the overall consumption of local and regional natural resources. Between 2000 and 2010, the population of Oregon grew 12.0% (U.S. Census Bureau 2012). Between 2010 and 2020, the population of Oregon is projected to grow another 12.4% (Oregon Office of Economic Analysis 2017).

Areas of faster growing population, such as Portland and the Willamette Valley, are likely to experience greater resource demands, and therefore produce adverse environmental effects to the action area. However, land use laws and progressive policies related to long-range planning will help to limit those impacts by ensuring that concern for a healthy economy that generates jobs and business opportunities is balanced by concern for protection of farms, forests, rivers, streams and natural areas (Metro 2000, Metro 2008, Metro 2011). In addition to land use planning to minimize adverse environmental impacts, larger population centers may also partly offset the adverse effects of their growing resource demands with more river restoration projects designed to provide ecosystem-based cultural amenities, although the geographic distribution of those actions, and therefore any benefits to ESA-listed species or critical habitats, may occur far from the centers of human populations.

Similarly, demand for cultural and aesthetic amenities continues to grow with human population, and is reflected in decades of concentrated effort by Tribes, states, and local communities to restore an environment that supports flourishing wildlife populations, including populations of species that are now ESA-listed (CRITFC 1995, OWEB 2017). Reduced economic dependence on traditional resource-based industries has been associated with growing public appreciation for the economic benefits of river restoration, and growing demand for the cultural amenities that river restoration provides. Thus, many non-Federal actions have become responsive to the recovery needs of ESA-listed species. Those actions included efforts to ensure that resource-based industries adopt improved practices to avoid, minimize, or offset their adverse impacts. Many actions are focused on completion of river restoration projects specifically designed to broadly reverse the major factors now limiting the survival of ESA-listed species at all stages of their life cycle. Those actions have improved the availability and quality of estuarine habitats, floodplain connectivity, channel structure and complexity, riparian areas and large wood recruitment, stream substrates, stream flow, water quality, and fish passage. In this way, the goal of ESA-listed species recovery has become institutionalized as a common and accepted part of the economic and environmental culture. We expect this trend to continue into the future as awareness of environmental and at-risk species issues increases among the general public.

It is not possible to predict the future intensity of specific non-Federal actions due to uncertainties about the economy, funding levels for restoration actions, and individual investment decisions. However, the adverse effects of resource-based industries in the action area are likely to continue in the future, although their net adverse effect is likely to decline slowly as beneficial effects spread from the adoption of industry-wide standards for more protective management practices. These effects, both negative and positive, will be expressed most strongly in rural areas where these industries occur, and therefore somewhat in contrast to human population density.

In summary, resource-based activities such as timber harvest, agriculture, mining, shipping, and energy development are likely to continue to exert an influence on the quality of habitat in the action area. The intensity of this influence is difficult to predict and is dependent on many social and economic factors. However, the adoption of industry-wide standards to reduce environmental impacts and the shift away from resource extraction to a mixed manufacturing and technology based economy should result in a gradual decrease in influence over time. In contrast, the population of Oregon is expected to increase in the next several decades with a corresponding increase in natural resource consumption. Additional residential and commercial development and a general increase in human activities are expected to cause localized degradation of freshwater and estuarine habitat. Interest in restoration activities is also increasing as is environmental awareness among the public (including the benefits of beaver). When these influences are considered collectively, we expect trends in habitat quality to remain flat or improve gradually over time. This will, at best, have positive influence on population abundance and productivity for the species affected by this consultation. In a worst cases scenario, we expect cumulative effects will have a relatively neutral effect on population abundance trends. Similarly, we expect the quality and function of critical habitat PBFs to express a slightly positive to neutral trend over time as a result of the cumulative effects.

2.7 Integration and Synthesis

The Integration and Synthesis section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action (Section 2.5) to the environmental baseline (Section 2.4) and the cumulative effects (Section 2.6), taking into account the status of the species and critical habitat (Section 2.2), to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) Reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) appreciably diminish the value of designated or proposed critical habitat as a whole for the conservation of the species.

2.7.1 Critical Habitat

Much of the action area is designated as critical habitat for ESA-listed salmon and steelhead. CHART teams determined that most of this critical habitat has a high conservation value. Baseline conditions for PBFs vary widely, from poor to excellent. Climate change and human development have and continue to adversely impact critical habitat, creating limiting factors and threats to the recovery of the ESA listed species. Climate change will likely result in a generally negative trend for stream flow and temperature. Information in Section 2.3 described the environmental baseline in the action area. We determined the environmental baseline throughout most of the action area is degraded due to one or more impaired aquatic habitat functions related to factors limiting the recovery of the species.

In the analysis of the effects of the action on critical habitat, we found the proposed action will remove beaver, resulting in loss of dams and beaver pond habitat because beavers will not maintain existing dams or build new ones. As a result, the benefits to PBFs provided by beaver ponds will degrade and be lost. We expect WS-Oregon to remove beaver from no more than 66 sites in critical habitat streams in any 5-year period. Beaver removal sites will be dispersed geographically across the action area. With the exception of the Coquille River HUC5 watershed, we expect WS-Oregon will remove beaver from four or less sites on streams with critical habitat within a 5-year period in any HUC5 watershed. Critical habitat PBFs will be adversely affected at a site level, but because of the spatial and temporal distribution of beaver removal, the proposed action is unlikely to affect the function of any PBFs for any listed ESU/DPS considered in this opinion at the watershed scale in any of these HUC5s. For the Coquille River HUC5, WS-Oregon's proposed action will result in only a small loss in acreage of beaver pond habitat within the Coquille River HUC5 and a very small portion of rearing habitat within HUC5, the proposed action will not affect critical habitat PBFs for OC coho salmon at the watershed scale. Thus, WS-Oregon's action will not affect critical habitat PBFs for OC coho salmon at the watershed scale for the Coquille River HUC5, either.

As described in Section 2.5, cumulative effects of future state and private actions are likely to have a neutral to slightly positive influence on critical habitat PBFs. Resource-based activities will continue to adversely affect critical habitat PBFs, but industry-wide standards and shifts away from resource extraction are reasonably certain to gradually decrease their effects over time. Human population of Oregon is expected to continue to increase causing localized degradation. Restoration activities and the public's growing environmental awareness (including the benefits of beaver) will reduce the impacts of some activities that may affect critical habitat.

Based on the above analysis, when considered in light of the status of the critical habitat, the effects of the proposed action, when added to the effects of the environmental baseline, and anticipated cumulative effects and climate change, the proposed action will not appreciably diminish the value of critical habitat for the conservation of any species considered in this opinion. Consequently, since the proposed action will not appreciably diminish the value of critical habitat for the conservation of any species at the critical habitat unit scale, it will not diminish the value of any critical habitat at the designation level and will retain its current ability to play the intended conservation role.

2.7.2 Listed Species

The status of each salmonid and steelhead species addressed by this consultation varies considerably from high risk of extinction (SR spring/summer-run Chinook salmon) to moderate risk (*e.g.,* OC coho salmon, MCR steelhead). Similarly, the individual populations within the ESU/DPS's affected by the proposed action vary considerably in their biological status. The species addressed in this opinion have declined due to numerous factors. The one factor for decline all these species share is degradation of freshwater and estuarine habitat. Human development has caused significant negative changes to stream and estuary habitat across the range of these species.

The environmental baseline has been degraded by the effects of past land and water use, beaver removal, road construction, forest management, agriculture, mining, transportation, urbanization, and water development. The severity of disturbance varies across the action area. Climate change is likely to exacerbate several of the ongoing habitat issues, in particular, increased summer temperatures, decreased summer flows in the freshwater environment, ocean acidification, and sea level rise in the estuarine environment.

As described in the analysis of the effects of the action (Section 2.5), the proposed action will remove beaver resulting in loss of dams and beaver pond habitat because beavers will not maintain existing dams or build new ones. Loss of the habitat created by beaver ponds will reduce salmonid carrying capacity of the stream forcing juveniles to move elsewhere to find forage and cover. Displaced fish will expend more energy searching for food or cover, resulting in slower growth and lower fitness. Thus, some juvenile salmon and steelhead displaced from beaver ponds will experience harm and potential death due to the indirect effects of beaver removal.

The proposed action is likely to have both positive and negative effects on adult and juvenile passage. Non-lethal management methods have negative effects, though much less than removing beavers.

Because of the few number of beaver removal sites and their expected spatial and temporal distribution, the affected proportion of any population of any ESU/DPS considered in this opinion will be low. The highest rate is 0.0002 % per year for the Coquille River population of OC coho salmon, where the number of beaver removal sites is an order of magnitude higher than any other population. Therefore, the proposed action will not appreciably negatively affect Chinook salmon, chum salmon, coho salmon, or steelhead abundance, productivity, spatial structure or diversity of any population, ESU or DPS.

Cumulative effects from future state and private activities described in Section 2.6 are likely to have a neutral to slightly positive effect over time on salmon and steelhead population abundance, productivity, and spatial structure. Resource-based activities will continue to adversely affect species, but industry-wide standards and shifts away from resource extraction will gradually decrease their effects over time. The human population of Oregon is expected to continue to increase causing localized degradation. Restoration activities and the public's growing environmental awareness (including the benefits of beaver) will reduce the impacts of some activities that may affect listed species.

At the ESU or DPS scale, the status of individual populations determines the ability of the species to sustain itself or persist well into the future, thus impacts to individual populations are important to the survival and recovery of the species. Because the adverse effects caused by the proposed action are small, when we add them to the current population status, environmental baseline, and consider cumulative effects and climate change, we find the proposed activities will not appreciably reduce the likelihood of the survival or recovery of any species at the population scale for any the affected populations. Given our conclusion that the populations will not be impeded in recovery as a result of the proposed action, it will also not appreciably reduce the likelihood of the survival or recovery of any species considered in this opinion at the ESU/DPS level.

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 cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of LCR Chinook salmon, UWR spring-run Chinook salmon, SR spring/summer-run Chinook salmon, SR fall-run Chinook salmon, CR chum salmon, LCR coho salmon, OC coho salmon, SONCC coho salmon, LCR steelhead, UWR steelhead, MCR steelhead, or SR steelhead, or destroy or adversely modify its designated critical habitat.

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). "Incidental take" is defined by regulation as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant (50 CFR 402.02). Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this ITS.

2.9.1 Amount or Extent of Take

In the biological opinion, we determined that incidental take is reasonably certain to occur as harm and potentially death to salmon and steelhead juveniles considered in this opinion as a result of rearing habitat loss due to beaver removals. This harm results from impairing rearing habitat by removing beaver which eliminates the benefits beaver ponds provide and by implementing non-lethal methods (pond levelers and deceivers) which may reduce some of those benefits and cause passage issues.

Take caused by the proposed action cannot be accurately quantified as a number of fish because the distribution and abundance of fish occurring near a beaver removal site are not fully predictable, and are affected by other factors including habitat quality, previous year's spawning density, competition, and predation. Thus, the distribution and abundance of fish within the action area cannot be attributed entirely to habitat conditions, nor can we precisely predict the number of fish reasonably certain to be harmed or killed by habitat modification due to the proposed action. Additionally, there is no practical way to count the number of fish exposed to the adverse effects of the proposed action without causing additional stress and injury. Thus, it is not practicable to quantify how many fish may be incidentally taken by the proposed action.

In such circumstances, we use a take surrogate which is causally linked to the expected level and type of incidental take from the proposed action. The take surrogate can be based on the extent of modifications to habitat. For the proposed action, the best available take surrogate is the number of sites on NMFS Trust Resource streams WS-Oregon removes beaver from, as follows:

1. Beaver removal at no more than 66 sites on NMFS Trust Resource streams over any 5-year period, excluding removals from stream channels greater than 33 feet wide at the ordinary high water mark or in lakes.[10]

2. A maximum of 22 of the 66 removals within the Coquille River HUC5 over any 5-year period.

3. A maximum of 4 of the 66 removals within any other HUC5 over any 5-year period.

NMFS will consider the extent of take exceeded if any of these situations occur – with the following exceptions:

1. If WS-Oregon successfully relocates beaver from one site on a NMFS Trust Resource stream to another site on a NMFS Trust Resource stream, it will not counts towards the statewide 5-year total (in 1, above). A successful relocation is defined as the relocated beaver being present at the relocation site and maintaining a beaver dam one year after release.

2. Removal from one site within a HUC5 will not count towards the HUC5 5-year total (in 2 or 3, above) if WS-Oregon successfully relocates beaver to a NMFS Trust Resource stream in that HUC5. A successful relocation is defined as the relocated beaver being present at the relocation site and maintaining a beaver dam one year after release

[10] Beavers are unlikely to successfully build dams in these areas (Suzuki and McComb 1998). Stream width at the ordinary high water mark needs to be measured at representative cross sections upstream and downstream of the removal site and averaged. For most streams, this the ordinary high water mark extends from the vegetation line on one streambank to the vegetation line on the opposite streambank. Measurement can typically be completed with ocular estimation.

These surrogates are connected causally to the amount of take that will occur because an increase in the number of removal sites and/or a geographic clustering of sites translates into a proportional increase in the impact to listed species. These surrogate metrics can be monitored and documented. This allows the surrogates to serve as clear reinitiation triggers. Although the surrogates are somewhat coextensive with the proposed action, they nevertheless serve as meaningful reinitiation triggers. Prior to removing beaver from a new site, in real-time WS-Oregon can check their database of sites they removed beavers from within the preceding five years. Furthermore, the surrogate metrics are reported on an annual basis, allowing easy determination if reinitiation is triggered.

2.9.2 Effect of the Take

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

2.9.3 Reasonable and Prudent Measures

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

WS-Oregon shall:

1. Minimize incidental take of NMFS Trust resources by promoting non-lethal beaver management alternatives.
2. Conduct monitoring sufficient to document the proposed action does not exceed the parameters analyzed in the effects section or the extent of take described above, and the terms and conditions are effective in minimizing incidental take.

2.9.4 Terms and Conditions

The terms and conditions described below are non-discretionary, WS-Oregon must comply with them in order to implement the RPMs (50 CFR 402.14). WS-Oregon 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 WS-Oregon does not comply with the following terms and conditions, protective coverage for the proposed action would likely lapse.

1. To implement reasonable and prudent measure #1 (promote non-lethal methods), WS-Oregon shall ensure:
   a. The landowner/requestor at every beaver removal site within or upstream from a NMFS Trust resource stream receives a copy of NMFS' beaver information pamphlet.[11]
   b. Prior to any repeated removals from the same site on a NMFS Trust Resource stream (defined as more than once, at least 6 months after the first removal but within a 5-year

[11] This pamphlet is scheduled for printing summer 2020, any WS action prior to pamphlet printing is exempt from this term and condition.

period), WS-Oregon will notify the Oregon Coast NMFS Branch Chief[12] (or designee) with at least 48 hours notice to discuss non-lethal alternatives. For any repeated lethal removals, WS-Oregon will document which non-lethal options were considered, why each non-lethal option was not implemented, and prepare an addendum to the annual report regarding the aforementioned information and options for non-lethal management at each of these sites in the future.

2. To implement reasonable and prudent measure #2 (monitoring and reporting), WS-Oregon shall ensure:
   a. NMFS is alerted within five business days if WS-Oregon exceeds a take threshold for any 5-year period.
   b. The following information is documented for every beaver removal site:
      i. Landowner's reason for requesting removal
      ii. GPS location of the removal site
      iii. Whether or not it is located on a NMFS Trust Resource stream
      iv. Whether or not there is beaver damming activity
      v. Visual estimate of area ponded by beaver dam, if any
   c. A monitoring report is submitted to NMFS by March 1 of each year that describes the previous year's implementation of the proposed action. At a minimum, WS-Oregon will provide the following:
      i. Information from Term and Condition 2b. above (except 2bii.)
      ii. The number of removal sites within NMFS Trust Resource streams, by HUC5
      iii. The cumulative number of removal sites within NMFS Trust Resource streams over the previous 5 years, by HUC5
      iv. The number and type of non-lethal activities implemented
      v. The number of attempted relocations and their success, by HUC5
      vi. The number of times a landowner/requestor called because of a beaver conflict but chose not to have WS-Oregon remove the beavers
      vii. Submit reports to:

         National Marine Fisheries Service
         West Coast Region
         Attn: WCRO-2018-00284
         1201 NE Lloyd Blvd Suite 1100
         Portland, Oregon 97232-1274

2.10 Conservation Recommendations

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

[12] The Oregon Coast Branch Chief can be reached at 541-957-3385

following conservation recommendation is a discretionary measure we believe is consistent with this obligation and therefore should be carried out by WS-Oregon:

1. We recommend WS-Oregon participate in efforts with us, U.S. Fish and Wildlife Service, ODFW, watershed councils, and other non-governmental organizations, within your authorities, to improve landowner outreach and funding programs to manage beaver where they exist using non-lethal methods.
2. We recommend WS-Oregon participate with us, U.S. Fish and Wildlife Service, ODFW, watershed councils, and other non-governmental organizations, within your authorities, in any new beaver relocation efforts by providing live-trapped beaver.

Please notify us if WS-Oregon carries out this recommendation, so that we will be kept informed of actions that minimize or avoid adverse effects and those that benefit the listed species or their designated critical habitats.

2.11 Reinitiation of Consultation

This concludes formal consultation for WS-Oregon's semiaquatic mammal damage management activities in Oregon.

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

2.12 "Not Likely to Adversely Affect" Determinations

This determination for UCR spring-run Chinook salmon, UCR steelhead, SR sockeye salmon, green sturgeon, and eulachon was prepared by us pursuant to section 7(a)(2) of the ESA, implementing regulations at 50 CFR 402 and agency guidance for preparation of letters of concurrence.

The applicable standard to find that a proposed action is not likely to adversely affect listed species or critical habitat is that all of the effects of the action are expected to be discountable, insignificant, or completely beneficial. Discountable effects are those extremely unlikely to occur. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs or where alteration of any PBFs of critical habitat reduces those features' ability to support listed species' conservation needs in the action area. Beneficial effects are contemporaneous positive effects without any adverse effect on the listed species or critical habitat. In terms of critical habitat, completely beneficial effects are positive only: an action cannot be deemed wholly beneficial if it has any adverse effect on critical habitat.

The proposed action and the action area for this consultation are described in the Introduction to this document (Sections 1.3 and 1.4).

2.12.1 Presence in the Action Area

UCR spring-run Chinook salmon and UCR steelhead

Within Oregon, UCR spring-run Chinook salmon and UCR steelhead are found only in the mainstem Columbia River. They use the Columbia River as a migration corridor between the ocean and their natal habitat in Washington streams. The portion in Oregon is designated critical habitat for both species.

SR sockeye salmon

Within Oregon, SR sockeye salmon are found only in the mainstem Columbia River and a portion of the mainstem Snake River. These river reaches are designated critical habitat. Individuals of this species use these rivers as a migration corridor between the ocean and their natal habitat in Idaho streams and lakes.

Green Sturgeon

Green sturgeon use Oregon estuaries for subadult and adult growth, development, and migration. Recent fieldwork indicates that green sturgeon generally inhabit specific areas of coastal estuaries near or within deep channels or holes, moving into the upper reaches of the estuary, but rarely into freshwater (WDFW and ODFW 2012). The Columbia River estuary from the mouth upstream to river mile 46 and the estuaries of Coos Bay, Winchester Bay, Yaquina Bay, and Nehalem Bay are designated critical habitat.

Eulachon

Eulachon have been observed in coastal rivers and estuaries in Oregon (Gustafson *et al.* 2010), but are described as rare by Monaco *et al*. 1990 (as cited in Gustafson *et al.* 2010) everywhere but in the Columbia River. In Oregon, we designated 143.2 miles of the mainstem Columbia River from the mouth to the base of Bonneville Dam, 24.2 miles of the lower Umpqua River, 12.4 miles of the lower Sandy River, and 0.2 miles of Tenmile Creek as critical habitat.

2.12.2 Effects on Listed Species

The opinion detailed the adverse effects of the proposed action on other ESU/DPSs and their designated critical habitats in section 2.4. That analysis completely overlaps geographically the species addressed in this section. Because of the similarity in habitat use and biology of these species, the analysis in section 2.4 helps inform our determinations here. Most importantly, the discussion of losing rearing habitat from loss of beaver dams applies to the following species.

UCR spring-run Chinook salmon and UCR steelhead

Within Oregon, these species are only found within the Columbia River, which is too large for beavers to build dams in (Suzuki and McComb 1998). Because beavers in the Columbia River cannot build dams, WS-Oregon's removal of beaver will not result in loss of beneficial beaver pond habitat. Furthermore, WS-Oregon did not remove any beaver from the mainstem Columbia River during the 5-year analysis period. Therefore, effects on UCR spring-run Chinook salmon or UCR steelhead or their designated critical habitats from beaver removal due to the proposed action are extremely unlikely and therefore discountable.

SR sockeye salmon

Within Oregon, this species is only found within the Columbia River and Snake River, both of which are too large for beavers to build dams in (Suzuki and McComb 1998). Because beavers in these rivers cannot build dams, WS-Oreogn's removal of beaver will not result in loss of beneficial beaver pond habitat. Furthermore, WS-Oregon did not remove any beaver from the mainstem Columbia River or Snake River during the 5-year analysis period. Therefore, effects on SR sockeye salmon or their designated critical habitat from beaver removal due to the proposed action are extremely unlikely and therefore discountable.

Green sturgeon

Within Oregon, this species occurs in estuaries where they mostly inhabit deepwater areas (WDFW and ODFW 2012). Beavers may build dams in small tidal channels, but not in the deepwater areas inhabited by green sturgeon. Therefore, WS-Oregon's removal of beaver will not result in loss of habitat beneficial to green sturgeon. Furthermore, WS-Oregon did not remove any beaver from any estuaries during the 5-year analysis period. Therefore, effects on green sturgeon or their designated critical habitat from beaver removal due to the proposed action are extremely unlikely and therefore discountable.

Eulachon

Adult eulachon spawn in the first stream reaches above head of tide in large rivers. Larval eulachon, which are feeble swimmers, are carried downstream within hours or days after hatching (Parente and Snyder 1970, Samis 1977, Howell 2001). Within Oregon, this species only inhabits estuaries and large tributaries, which are too large for beavers to build dams. Because beavers do not build dams in areas where eulachon are found, WS-Oregon's removal of beaver will not result in loss of habitat beneficial to eulachon. Furthermore, WS-Oregon did not remove any beaver from estuaries during the 5-year analysis period. Therefore, effects on eulachon or their designated critical habitat from the proposed action are extremely unlikely and therefore discountable.

2.12.3 Conclusion

Based on this analysis, NMFS determines the proposed action is not likely to adversely affect UCR spring-run Chinook salmon, UCR steelhead, SR sockeye salmon, green sturgeon, eulachon, or their critical habitats.

2.12.4 Reinitation

The reinitiation requirements set out in Section 2.11 of the opinion are also applicable to the not likely to adversely affect determinations in this section. This concludes the ESA portion of this consultation.

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

Section 305(b) of the MSA directs Federal agencies to consult with NMFS on all actions or proposed actions that may adversely affect EFH. The MSA (section 3) defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." Adverse effect means any impact that reduces quality or quantity of EFH, and may include direct or indirect physical, chemical, or biological alteration of the waters or substrate and loss of (or injury to) benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality or quantity of EFH. Adverse effects on EFH may result from actions occurring within EFH or outside of it and may include site-specific or EFH-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810). Section 305(b) also requires NMFS to recommend measures that can be taken by the action agency to conserve EFH.

This analysis is based, in part, on the descriptions of EFH for Pacific Coast salmon (PFMC 2014) contained in the fishery management plans developed by the Pacific Fishery Management Council (PFMC) and approved by the Secretary of Commerce.

3.1 Essential Fish Habitat Affected by the Project

The proposed program and action area for this consultation are described in the Introduction to this document. The program action area includes areas designated as EFH for various life-history stages of Pacific Coast salmon (Chinook, chum, and coho salmon). In addition, estuaries are defined as habitat areas of particular concern (HAPCs).

3.2 Adverse Effects on Essential Fish Habitat

The ESA portion of this document (Section 2.5) describes the adverse effects of this proposed action on Chinook salmon, chum salmon, and coho salmon. This ESA analysis of effects is also relevant to Pacific Coast salmon EFH. Based on information provided by the action agency and the analysis of effects presented in the ESA portion of this document, we conclude that the proposed action will adversely affect designated EFH due to loss of benefits beaver ponds provide.

As explained in the section 2.5.1 above, to give benefit of the doubt to the species and analyze the worst case scenario, we have to make assumptions about the value of beaver ponds and the longevity of beaver dams after WS-Oregon removes the beaver. We assume all beaver dams positively affect salmonid habitat (except passage). We also assume when WS-Oregon removes beaver from a site, it results in loss of a beaver dam and associated pond. Pacific salmon evolved with beaver dams and adapted to their presence. Pollock *et al*. (2017) and Pollock *et al*. (2004) completed extensive reviews of how beaver dams affect the hydrology, water quality, and geomorphology of streams. Beaver dams can play a critical role in replenishing alluvial aquifers by trapping and storing water, redirecting surface water onto adjacent floodplains, and forcing water into the streambed and banks. Beaver dams slow stream flows, holding the water within the stream reach for longer periods, which can increase base flows. Beaver dams create surface pools and ponds, transforming moving-water habitats to a combination of moving- and slow-water habitat and lead to an expansion of riparian and wetland habitats along streams. Beaver ponds add habitat complexity, including variation in temperatures, depths, and velocities, as well as potential prey diversity (McDowell and Naiman 1986, Wathen *et al*. 2018, Weber *et al*. 2017). All of these effects benefit salmon survival and abundance. Recent studies in the Lower Klamath, Middle Klamath and Shasta sub-basins confirm that beaver ponds provide high quality summer and winter rearing habitat for coho salmon (Chesney *et al*. 2009, Silloway 2010).

3.3 Essential Fish Habitat Conservation Recommendations

The following three conservation measures are necessary to avoid, mitigate, or offset the impact of the proposed action on EFH. All of these conservation recommendations are a subset of the ESA terms and conditions.

1. Promote non-lethal methods. Minimize adverse effects from beaver removal by promoting non-lethal management, as stated in term and condition #1 in the accompanying opinion.
2. Monitoring and reporting. Ensure completion of monitoring and reporting to confirm the proposed action is meeting the objective of limiting adverse effects, as stated in term and condition #2 in the accompanying opinion.
3. Participate in outreach programs. Participate in efforts to improve landowner outreach and funding programs to manage beaver where they exist using non-lethal methods, as stated in conservation recommendation #1 in the accompanying opinion.
4. Participate in relocation efforts. Participate in any new beaver relocation efforts by providing live-trapped beaver, as stated in conservation recommendation #2 in the accompanying opinion.

3.4 Statutory Response Requirement

As required by section 305(b)(4)(B) of the MSA, WS-Oregon 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 WS-Oregon have agreed to use alternative time frames for the Federal agency response. The response must include a description of measures proposed by the agency for avoiding, minimizing, mitigating, or otherwise offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the Conservation Recommendations, the Federal agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the action and the measures needed to avoid, minimize, mitigate, or offset such effects (50 CFR 600.920(k)(1)).

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

3.5 Supplemental Consultation

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

4.1 Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended user of this opinion is WS-Oregon. Individual copies of this opinion were provided to WS-Oregon. The format and naming adheres to conventional standards for style.

4.2 Integrity

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

4.3 Objectivity

Information Product Category: Natural Resource Plan

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

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

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

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

5. REFERENCES

Abatzoglou, J.T., D.E. Rupp, and P.W. Mote. 2014. Seasonal climate variability and change in the Pacific Northwest of the United States. Journal of Climate 27(5): 2125-2142.

Alpers, C.N., R.C. Antweiler, H.E. Taylor, P.D. Dileanis, and J.L. Domagalski (editors). 2000a. Volume 2: Interpretation of metal loads.In: Metals transport in the Sacramento River, California, 1996-1997, Water-Resources Investigations Report 00-4002. U.S. Geological Survey. Sacramento, California.

Alpers, C.N., R.C. Antweiler, H.E. Taylor, P.D. Dileanis, and J.L. Domagalski (editors). 2000b. Volume 1: Methods and Data.In: Metals transport in the Sacramento River, California, 1996-1997, Water-Resources Investigations Report 99-4286. U.S. Geological Survey. Sacramento, California.

Baldwin, D.H., J.A. Spromberg, T.K. Collier, and N.L. Scholz. 2009. A fish of many scales: extrapolating sublethal pesticide exposures to the productivity of wild salmon populations. Ecological Applications 19(8):2004-2015.

Baldwin, D.H., C.P. Tatara, and N.L. Scholz. 2011. Copper-induced olfactory toxicity in salmon and steelhead: Extrapolation across species and rearing environments. Aquatic Toxicology 101:295-297.

Beechie, T., M. Pollock, and S. Baker. 2008. Channel incision, evolution and potential recovery in the Walla Walla and Tucannon River basins, northwestern USA. Earth Surface Processes and Landforms 33:784-800.

Bilton, H.T., D.F. Alderdice, and J.T. Schnute. 1982. Influence of time and size at release of juvenile coho salmon (*Oncorhynchus kisutch*) on returns at maturity. Canadian Journal of Fisheries and Aquatic Sciences 39:426-447.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. In Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society special publication 19:83-138.

Bourret, S.L., C.C. Caudill, and M.L. Keefer. 2016. Diversity of juvenile Chinook salmon life history pathways. Reviews in Fish Biology and Fisheries: 1–29.

Bouwes, N., N. Weber, C.E. Jordan, W.C. Saunders, I.A. Tattam, C. Volk, J.M. Wheaton, and M.M. Pollock. 2016. Ecosystem experiment reveals benefits of natural and simulated beaver dams to a threatened population of steelhead (*Oncorhynchus mykiss*). Scientific reports, 6, 28581.

Bricker, O.P. 1999. An overview of the factors involved in evaluation the geochemical effects of highway runoff on the environment. U.S. Geological Survey, and Federal Highway Administration. Open-File Report 98-630. Northborough, Massachusetts.

Brown, K. (compiler and producer). 2011. Oregon Blue Book: 2011-2012. Oregon State Archives, Office of the Secretary of State of Oregon. Salem, Oregon. http://bluebook.state.or.us/.

Brown, L.R., P.B. Moyle, and R.M. Yoshiyama. 1994. Historical decline and current status of coho salmon in California. Department of Wildlife and Fisheries Biology, University of California, Davis.

Bustard, D.R., and D.W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of Fisheries Research Board of Canada 32:667–680.

Carls, M.G., and J.P. Meador. 2009. A perspective on the toxicity of petrogenic PAHs to developing fish embryos related to environmental chemistry. Human and Ecological Risk Assessment: An International Journal 15(6):1084-1098.

Carpenter, K.D., S. Sobieszczyk, A.J. Arnsberg, and F.A. Rinella. 2008. Pesticide Occurrence and Distribution in the Lower Clackamas River Basin, Oregon, 2000–2005. U.S. Geological Survey Scientific Investigations Report 2008-5027:98 p.

Chadwick, D.B., A. Zirino, I. Rivera-Duarte, C.N. Katz, and A.C. Blake. 2004. Modeling the mass balance and fate of copper in San Diego Bay. Limnology and Oceanography 49:355-366.

Chesney, W.R., C.C. Adams, W.B. Crombie, H.D. Langendorf, S.A. Stenhouse, and K.M. Kirkby. 2009. Shasta River juvenile coho habitat and migration study. California Department of Fish and Game, Sacramento, California.

Collen, P., and R.J. Gibson. 2000. The general ecology of beavers (*Castor* spp.), as related to their influence on stream ecosystems and riparian habitats, and the subsequent effects on fish - a review. Reviews in Fish Biology and Fisheries 10:439-461.

CRITFC (Columbia River Inter-Tribal Fish Commission). 1995. Wy-Kan-Ush-Mi Wa-Kish-Wit: Spirit of the salmon, the Columbia River anadromous fish restoration plan of the Nez Perce, Umatilla, Warm Springs, and Yakama Tribes. Two volumes. Columbia River Inter-Tribal Fish Commission and member Tribes. Portland, Oregon. http://www.critfc.org/fish-and-watersheds/fish-and-habitat-restoration/the-plan-wy-kan-ush-mi-wa-kish-wit/.

Copeland, T., M.W. Ackerman, K.K. Wright, A. Byrne. 2017. Life History Diversity of Snake River Steelhead Populations between and within Management Categories. North American Journal of Fisheries Management 37:395–404.

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

Crozier, L.G., M.D. Scheuerell, and E.W. Zabel. 2011. Using Time Series Analysis to Characterize Evolutionary and Plastic Responses to Environmental Change: A Case Study of a Shift Toward Earlier Migration Date in Sockeye Salmon. *The American Naturalist* 178 (6): 755-773.

Deisch, M.S. 1986. The effects of three rodenticides on non-target small mammals and invertebrates. Unpublished thesis, South Dakota State University, Brookings. 149 pp.

Deisch, M.S., D.W. Uresk, and R.L. Linder. 1989. Effects of two prairie dog rodenticides on ground dwelling invertebrates in western South Dakota. Pages 166-170 in Ninth Great Plains wildlife damage control workshop proceedings. USDA Forest Service General Technical Report RM-171. 181 pp.

Demmer, R., and R.L. Beschta. 2008. Recent history (1988–2004) of beaver dams along Bridge Creek in central Oregon. Northwest Science, 82(4):309-318.

Dominguez, F., E. Rivera, D.P. Lettenmaier, and C.L. Castro. 2012. Changes in Winter Precipitation Extremes for the Western United States under a Warmer Climate as Simulated by Regional Climate Models. *Geophysical Research Letters* 39(5).

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

Everest, F.H., and D.W. Chapman. 1972. Habitat selection and spatial interaction by juvenile Chinook salmon and steelhead trout in two Idaho streams. Journal of the Fisheries Research Board of Canada 29: 91–100.

Everest, F.H., and coauthors. 1986. Abundance, behavior, and habitat utilization by coho salmon and steelhead trout in Fish Creek, Oregon, as influenced by habitat enhancement. Annual Report 1985. U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Project No. 84–11, Corvallis, Oregon.

Feely, R.A., T. Klinger, J.A. Newton, and M. Chadsey (editors). 2012. Scientific summary of ocean acidification in Washington state marine waters. NOAA Office of Oceanic and Atmospheric Research Special Report.

Ferguson, J.W., G.M. Matthews, R.L. McComas, R.F. Absolon, D.A. Brege, M.H. Gessel, and L.G. Gilbreath. 2005. Passage of adult and juvenile salmonids through federal Columbia River power system dams. U.S. Department of Commerce. NOAA Technical Memorandum NMFS-NWFSC-64. 160 p.

Fuhrer, G.J., D.Q. Tanner, J.L. Morace, S.W. McKenzie, and K.A. Skach. 1996. Water quality of the Lower Columbia River Basin: Analysis of current and historical water-quality data through 1994. U.S. Geological Survey. Water-Resources Investigations Report 95-4294. Reston, Virginia.

Gilliom, R.J., J.E. Barbash, C.G. Crawford, P.A. Hamilton, J.D. Martin, N. Nakagaki, L.H. Nowell, J.C. Scott, P.E. Stackelberg, G.P. Thelin, and D.M. Wolock. 2006. Pesticides in the nation's streams and ground water, 1992-2001. U.S. Geological Survey Circular 1291:172 p.

Glick, P., J. Clough, and B. Nunley. 2007. Sea-Level Rise and Coastal Habitats in the Pacific Northwest: An analysis for Puget Sound, southwestern Washington, and northwestern Oregon. National Wildlife Federation, Seattle, WA.

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

Green, K.C., and C.J. Westbrook. 2009. Changes in riparian area structure, channel hydraulics, and sediment yield following loss of beaver dams. BC Journal of Ecosystems and Management 10(1):68–79.

Gustafson, R.G., M.J. Ford, D. Teel, and J.S. Drake. 2010. Status review of eulachon (Thaleichthys pacificus) in Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-105, 360 p.

Hays, D.B., C.P. Ferreri, and W.W. Taylor. 1996. Linking fish habitat to their population dynamics. Canadian Journal of Fisheries and Aquatic Sciences. 53(1):383-390.

Hicken, C.E., T.L. Linbo, D.H. Baldwin, M.L. Willis, M.S. Myers, L. Holland, M. Larsen, M.S. Stekoll, S.D. Rice, T.K. Collier, N.L. Scholz, and J.P. Incardona. 2011. Sublethal exposure to crude oil during embryonic development alters cardiac morphology and reduces aerobic capacity in adult fish. Proceedings of the National Academy of Sciences 108(17):7086-7090.

Hood, W.G. 2012. Beaver in Tidal Marshes: Dam Effects on Low-Tide Channel Pools and Fish Use of Estuarine Habitat. Wetlands 32:401-410.

Howell, M.D. 2001. Characterization of development in Columbia River prolarval eulachon, Thaleichthys pacificus, using selected morphometric characters. Washington Department of Fish and Wildlife, Vancouver, WA.

ISAB (editor) (Independent Scientific Advisory Board). 2007. Climate change impacts on Columbia River Basin fish and wildlife. *In:* Climate Change Report, ISAB 2007-2. Independent Scientific Advisory Board, Northwest Power and Conservation Council. Portland, Oregon.

IPCC (Intergovernmental Panel on Climate Change). 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

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

Johnson, V.G., R.E. Peterson, and K.B. Olsen. 2005. Heavy metal transport and behavior in the lower Columbia River, USA. Environmental Monitoring and Assessment 110:271-289.

Johnson, L., B. Anulacion, M. Arkoosh, O.P. Olson, C. Sloan, S.Y. Sol, J. Spromberg, D.J. Teel, G. Yanagida, and G. Ylitalo. 2013. Persistent organic pollutants in juvenile Chinook salmon in the Columbia River Basin: Implications for stock recovery. Transactions of the American Fisheries Society 142:21-40.

Kemp, P.S., T.A. Worthington, T.E. Langford, A.R. Tree, and M.J. Gaywood. 2012. Qualitative and quantitative effects of reintroduced beavers on stream fish. Fish and Fisheries 13:158-181.

Kiely, T., D. Donaldson, and A. Grube. 2004. Pesticides industry sales and usage 2000 and 2001 market estimates. U.S. Environmental Protection Agency, Biological and Economic Analysis Division. http://www.epa.gov/opp00001/pestsales/01pestsales/market_estimates2001.pdf.

Kunkel, K.E., L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, K.T. Redmond, and J.G. Dobson. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 6. *Climate of the Northwest U.S. NOAA Technical Report NESDIS 142-6*. 83 pp. National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service, Washington, D.C.

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

Leidholt-Bruner, K., D.E. Hibbs, and W.C. McComb. 1992. Beaver dam locations and their effects on distribution and abundance of coho salmon fry in two coastal Oregon streams. Northwest Science 66(4):218–223.

Lower Columbia Fish Recovery Board. 2010. Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan.

Lowry, M.M. 1993. Groundwater elevations and temperature adjacent to a beaver pond in central Oregon. Oregon State University, Oregon State University, Corvallis.

Macneale, K.H., P.M. Kiffney, and N.L. Scholz. 2010. Pesticides, aquatic food webs, and the conservation of Pacific salmon. Frontiers in Ecology and the Environment 8(9):475-482.

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

Malison, R.L., L.A. Eby, and J.A. Stanford. 2015. Juvenile salmonid growth, survival, and production in a large river floodplain modified by beavers (*Castor canadensis*). Canadian Journal of Fisheries and Aquatic Sciences 72:1639–1651.

Malison, R.L., K.V. Kuzishchin, and J.A. Stanford. 2016. Do beaver dams reduce habitat connectivity and salmon productivity in expansive river floodplains? PeerJ 4(e2403).

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

McComb, W.C., J.R. Sedell, and T.D. Buchholz. 1990. Dam-site selection by beavers in an eastern Oregon Basin. The Great Basin Naturalist Vol. 50: 273-281

McDowell, D.M., and R.J. Naiman. 1986. Structure and function of a benthic invertebrate stream community as influenced by beaver (*Castor canadensis*). Oecologia 68:481-489.

McKinstry, M., and S. Anderson. 2002. Survival, Fates, and Success of Transplanted Beavers, *Castor canadensis*, in Wyoming. Canadian Field-Naturalist 116:60-68.

McMahon, T.E., and G.F. Hartman. 1989. Influence of cover complexity and current velocity on winter habitat use by juvenile coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 46: 1551–1557.

McRae, G. and C.J. Edwards. 1994. Thermal characteristics of Wisconsin headwater streams occupied by beaver: Implications for brook trout habitat. Trans. Am. Fish. Soc. 123:641-656.

Metro. 2000. The nature of 2040: The region's 50-year plan for managing growth. Metro. Portland, Oregon. http://library.oregonmetro.gov/files/natureof2040.pdf.

Metro. 2008. The Portland metro region: Our place in the world – global challenges, regional strategies, homegrown solutions. Metro. Portland, Oregon. http://library.oregonmetro.gov/files/our_place_in_the_world.pdf.

Metro. 2010. Urban Growth Report: 2009-2030, Employment and Residential. Metro. Portland, Oregon. January. http://library.oregonmetro.gov/files/ugr.pdf.

Metro. 2011. Regional Framework Plan: 2011 Update. Metro. Portland, Oregon. http://library.oregonmetro.gov/files//rfp.00_cover.toc.intro_011311.pdf.

Meyer, J.L., M.J. Sale, P.J. Mulholland, and N.L. Poff. 1999. Impacts of climate change on aquatic ecosystem functioning and health. Journal of the American Water Resources Association 35(6): 1373-1386.

Monaco, M.E., R.L. Emmett, S.A. Hinton, and D.M. Nelson. 1990. Distribution and abundance of fishes and invertebrates in West Coast estuaries. Volume I: Data summaries. ELMR Rep. No. 4, Strategic Assessment Branch, NOS/NOAA. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service.

Morace, J.L. 2012. Reconnaissance of contaminants in selected wastewater-treatment-plant effluent and stormwater runoff entering the Columbia River, Columbia River Basin, Washington and Oregon, 2008–10. U.S. Geological Survey. Scientific Investigations Report 2012-5068. Reston, Virginia.

Mote, P.W., J.T. Abatzglou, and K.E. Kunkel. 2013. Climate: variability and change in the past and the future. In: Climate change in the Northwest: implications for our landscapes, waters, and communities, edited by M. M. Dalton, P. W. Mote, and A. K. Snover, Island Press, Washington, D.C.

Mote, P.W, A.K. Snover, S. Capalbo, S.D. Eigenbrode, P. Glick, J. Littell, R.R. Raymondi, and W.S. Reeder. 2014. Ch. 21: Northwest. In Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, T.C. Richmond, and G.W. Yohe, Eds., U.S. Global Change Research Program, 487-513.

Mote, P.W., D.E. Rupp, S. Li, D.J. Sharp, F. Otto, P.F. Uhe, M. Xiao, D.P. Lettenmaier, H. Cullen, and M.R. Allen. 2016. Perspectives on the cause of exceptionally low 2015 snowpack in the western United States, Geophysical Research Letters, 43.

Moyle, P. 2002. Inland fishes of California, 2nd edition, Berkeley, University of California Press.

Murphy, M.L., J. Heifetz, J.F. Thedinga, S.W. Johnson, and K.V. Koski. 1989. Habitat Utilization by Juvenile Pacific Salmon (*Onchorynchus*) in the Glacial Taku River, Southeast Alaska. Canadian Journal of Fisheries and Aquatic Science 46:1677–1685.

Myrvold, K.M., and B.P. Kennedy. 2016. Juvenile steelhead movements in relation to stream habitat, population density, and body size: consequences for individual growth rates. Canadian Journal of Fisheries and Aquatic Sciences. 73:1520–1529.

Naiman, R.J., J.M. Melillo, and J.E. Hobbie. 1986. Ecosystem Alteration of Boreal Forest Streams by Beaver (*Castor Canadensis*). Ecology 67(5):1254–1269.

Naiman, R. J., C.A. Johnston, and J.C. Kelley. 1988. Alteration of North American streams by beaver. BioScience 38:753-761.

Narver, D.W. 1978. Ecology of juvenile coho salmon: can we use present knowledge for stream enhancement? Pages 38-42 in B. G. Shephard and R. M. J. Grinetz (eds.). Proceedings of the 1977 Northeast Pacific chinook and coho salmon workshop. Department of Fisheries and Environment. Vancouver. Canada Fisheries Marine Service Technical Report 759.

Nickelson, T.E., J.D. Rodgers, S.L. Johnson, and M.F. Solazzi. 1992. Seasonal changes in habitat use by juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 49:783-789.

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

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

NMFS (National Marine Fisheries Service). 2011. Endangered Species Act - Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead. Portland, Oregon. August 5, 2011.

NMFS (National Marine Fisheries Service). 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. June.

NMFS (National Marine Fisheries Service). 2014. Final recovery plan for the Southern Oregon/Northern California Coast evolutionarily significant unit of coho salmon (*Oncorhynchus kisutch*). National Marine Fisheries Service. Arcata, California.

NMFS (National Marine Fisheries Service). 2015. ESA Recovery for Snake River Fall Chinook Salmon. West Coast Region, Protected Resources Division, Portland, OR, 97232.

NMFS (National Marine Fisheries Service). 2016a. Recovery plan for Oregon Coast coho salmon evolutionarily significant unit. West Coast Region, Portland, Oregon.

NMFS (National Marine Fisheries Service). 2016b. ESA Recovery Plan for Snake River Spring/Summer Chinook Salmon and Snake River Steelhead. West Coast Region, Protected Resources Division, Portland, OR.

NMFS (National Marine Fisheries Service). 2016c. 5-year review: summary and evaluation of Southern Oregon/Northern California Coast coho salmon. West Coast Region, Arcata, California.

NRC (National Research Council). 2009. Urban Stormwater Management in the United States. National Research Council. The National Academies Press. Washington, D.C.

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

ODEQ (Oregon Department of Environmental Quality). 2012. Stormwater management plan submission guidelines for removal/fill permit applications which involve impervious surfaces. July 2005 Updated December 2008 & January 2012. Oregon Department of Environmental Quality. Portland, Oregon.

ODFW (Oregon Department of Fish and Wildlife). 2010. Lower Columbia River Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead. Oregon Department of Fish and Wildlife.

ODFW (Oregon Department of Fish and Wildlife). 2018. Oregon furtakers license and harvest data. June 7, 2018. Salem, OR.

ODFW (Oregon Department of Fish and Wildlife). 2019. Oregon Coast coho ESU adult spawning abundance by strata and population, 2004-2018. ODFW. Corvallis, Oregon. https://odfw.forestry.oregonstate.edu/spawn/pdf%20files/coho/AnnualEstOC2004-2018.pdf

Oregon Office of Economic Analysis. 2017. Oregon economic and revenue forecast. Appendix C: Population forecast by age and sex. http://www.oregon.gov/DAS/OEA/docs/economic/appendixc.pdf.

OWEB (Oregon Watershed Enhancement Board). 2017. The Oregon Plan for Salmon and Watersheds: Biennial Report 2015-2017 Executive Summary. Oregon Watershed Enhancement Board. Salem, Oregon. http://www.oregon.gov/OPSW/docs/OPSW-BR-Exec-2015-17.pdf

Parente, W.D., and G.R. Snyder. 1970. A pictorial record of the hatching and early development of the eulachon (*Thaleichthys pacificus*). Northwest Science 44:50-57.

Peterson, T.P., J.L. Fisher, C.A. Morgan, S.M. Zeman, B.J. Burke, K.C. Jacobson. 2018. Ocean Ecosystem Indicators of Salmon Marine Survival in the Northern California Current. Northwest Fisheries Science Center, National Marine Fisheries Service. Newport, Oregon. 93 p.

Petro, V.M. 2013. Evaluating" nuisance" beaver relocation as a tool to increase coho salmon habitat in the Alsea Basin of the central Oregon Coast Range. Masters Thesis, Oregon State University.

PFMC (Pacific Fishery Management Council). 2014. Appendix A to the Pacific Coast Salmon Fishery Management Plan, as modified by Amendment 18. Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon.

Pollock, M.M., T.J. Beechie, and C.E. Jordan. 2007. Geomorphic changes upstream of beaver dams in Bridge Creek, an incised stream channel in the interior Columbia River basin, eastern Oregon. Earth Surface Processes and Landforms 32(8):1174–1185.

Pollock, M.M., M. Heim, and D. Werner. 2003. Hydrologic and Geomorphic Effects of Beaver Dams and Their Influence on Fishes. Pages 213–233 in S. V. Gregory, K. Boyer, and A. Gurnell, editors. American Fisheries Society Symposium 37:1–20.

Pollock, M.M., G.E. Pess, T.J. Beechie, and D.R. Montgomery. 2004. The importance of beaver ponds to Coho salmon production in the Stillaguamish River Basin, Washington, USA. North American Journal of Fisheries Management 24(3):749–760.

Pollock, M., G. Lewallen, K. Woodruff, C. Jordan, and J. Castro. 2017. The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains. Version 2.0. United States Fish and Wildlife Service, Portland, Oregon.

Ponce, V.M., and D.S. Lindquist. 1990. Management of baseflow augmentation: A review. Journal of the American Water Resources Association 26(2):259–268.

Quinn, T.P., and N.P. Peterson. 1996. The influence of habitat complexity and fish size on over winter survival and growth of individually marked juvenile coho salmon (*Oncorhynchus kisutch*) in Big Beef Creek, Washington. Canadian Journal of Fisheries and Aquatic Sciences 53: 1555-1564.

Quinn, T.P. 2005. The behavior and ecology of Pacific salmon and trout. American Fisheries Society, Bethesda, MD.

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

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

Reeves, G.H., F.H. Everest, and T.E. Nickelson. 1989. Identification of Physical Habitats Limiting the Production of Coho Salmon in Western Oregon and Washington. PNW GTR 245, US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station.

Rinella, F.A., and M.L. Janet. 1998. Seasonal and spatial variability of nutrients and pesticides in streams of the Willamette Basin, Oregon, 1993–95. U.S. Geological Survey Water-Resources Investigations Report 97-4082-C:57 p.

Rosemond, A., and C. Anderson. 2003. Engineering role models: do non-human species have the answers? Ecological Engineering 20:379-387.

Samis, S.C. 1977. Sampling eulachon eggs in the Fraser River using a submersible pump. Fisheries and Marine Service Technical Report. PAC/T-77-18.

Scheuerell, M.D., and J.G. Williams. 2005. Forecasting climate-induced changes in the survival of Snake River spring/summer Chinook salmon (*Oncorhynchus tshawytscha*). Fisheries Oceanography 14:448-457.Shared Strategy for Puget Sound. 2007. Puget Sound salmon recovery plan. Volume 1, recovery plan. Shared Strategy for Puget Sound. Seattle.

Silloway, S. 2010. Fish Surveys Related to the Proposed Del Norte Highway 101 Klamath Grade Raise Project. Yurok Tribal Fisheries Program, Klamath, California.

Skeesick, D.G. 1970. The fall immigration of juvenile coho salmon into a small tributary. Fish Commission of Oregon, Research Division Research Report 2, Subject: Coho data collected during harvest monitoring activities on Yurok Indian Reservation, CA.

Slate, D.A., R. Owens, G. Connelly, and G. Simmons. 1992. Decision making for wildlife damage management. Transactions of the North American Wildlife and Natural Resource Conference 57:51-62.

Spromberg, J.A., and J.P. Meador. 2006. Relating chronic toxicity responses to population-level effects: A comparison of population-level parameters for three salmon species as a function of low-level toxicity. Ecological Modeling 199:240-252.

Sridhara, S. 2016. Vertebrate pests in agriculture. Scientific Publishers. Delhi, India. 479 p.

Stout, H.A., P.W. Lawson, D.L. Bottom, T.D. Cooney, M.J. Ford, C.E. Jordan, R.J. Kope, L.M. Kruzic, G.R. Pess, G.H. Reeves, M.D. Scheuerell, T.C. Wainwright, R.S. Waples, E. Ward, L.A. Weitkamp, J.G. Williams, and T.H. Williams. 2012. Scientific conclusions of the status review for Oregon Coast coho salmon (*Oncorhynchus kisutch*). U.S. Department of Commerce. NOAA Technical Memorandum NMFS-NWFSC-118. 242 p.

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

Suzuki, N., and W.C. McComb. 1998. Habitat classification models for beaver (*Castor canadensis*) in the streams of the Central Oregon Coast Range. Northwest Science 72(2):102-110.

Swales, S., and C.D. Levings. 1989. Role of off-channel ponds in the life cycle of coho salmon (Oncorhynchus kisutch) and other juvenile salmonids in the Coldwater River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 46:232-242.

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

Tillmann, P., and D. Siemann. 2011. Climate Change Effects and Adaptation Approaches in Marine and Coastal Ecosystems of the North Pacific Landscape Conservation Cooperative Region. National Wildlife Federation.

Tripp, D., and P. McCart. 1983. Effects of different stocking strategies on coho and cutthroat trout production in isolated headwater streams. Canadian Technical Reports of Fisheries and Aquatic Sciences. 176 p.

U.S. Census Bureau. 2012. Statistical Abstract of the United States: 2012. Washington, D.C. https://www2.census.gov/library/publications/2011/compendia/statab/131ed/tables/pop.pdf

USEPA (U.S. Environmental Protection Agency). 2009. Columbia River Basin: State of the River Report for Toxics. U.S. Environmental Protection Agency, Region 10. Seattle.

USEPA (U.S. Environmental Protection Agency). 2011. 2011 Toxic Release Inventory National Analysis: Large Aquatic Ecosystems - Columbia River Basin. U.S. Environmental Protection Agency. http://www2.epa.gov/toxics-release-inventory-tri-program/2011-tri-national-analysis-large-aquatic-ecosystems-columbia.

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.

Wathen, G., J.E. Allgeier, N. Bouwes, M.M. Pollock, D.E. Schindler, and C.E. Jordan. 2018. Beaver activity increases habitat complexity and spatial partitioning by steelhead trout. Canadian Journal of Fisheries and Aquatic Sciences. Published on the web.

WDFW and ODFW (Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife). 2012. Submission in response to Federal Register notice (77 FR 64959).

Weber, N., and coauthors. 2017. Alteration of stream temperature by natural and artificial beaver dams. PLoS ONE 12:e0176313.

Wenger, S.J., D.J. Isaak, C.H. Luce, H.M. Neville, K.D. Fausch, J.B. Dunham, D.C. Dauwalter, M.K. Young, M.M. Elsner, and B.E. Rieman. 2011. Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change. Proceedings of the National Academy of Sciences:201103097.

Westbrook, C.J., D.J. Cooper, and B.W. Baker. 2006. Beaver dams and overbank floods influence groundwater-surface water interactions of a Rocky Mountain riparian area. Water resources research 42:1-12.

White, D.S. 1990. Biological relationships to convective flow patterns within stream beds. Hydrobiologia 196:149–158.

WS (Wildlife Services). 2003. WS Directive 2.501 Translocation of Wildlife. 7/30/03. https://www.aphis.usda.gov/wildlife_damage/directives/2.501_translocation_of_wildlife.pdf

WS (Wildlife Services). 2014. WS Directive 2.201 WS Decision Model. 7/15/14. https://www.aphis.usda.gov/wildlife_damage/directives/2.201_ws_decision_model.pdf

Williams, J.G., S.G. Smith, R.W. Zabel, W.D. Muir, M.D. Scheuerell, B.P. Sandford, D.M. Marsh, R.A. McNatt, and S. Achord. 2005. Effects of the Federal Columbia River Power System on salmon populations. U.S. Department of Commerce. NOAA Technical Memorandum NMFS-NWFSC-63. 150 p. http://www.nwfsc.noaa.gov/assets/25/6061_04142005_152601_effectstechmemo63final.pdf.

Winder, M., and D.E. Schindler. 2004. Climate change uncouples trophic interactions in an aquatic ecosystem. Ecology 85: 2100–2106.

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. Gen. Tech. Rep. PNW-GTR-326. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Portland, OR. 65 p.

Zabel, R.W., M.D. Scheuerell, M.M. McClure, and J.G. Williams. 2006. The interplay between climate variability and density dependence in the population viability of Chinook salmon. Conservation Biology 20(1):190-200.