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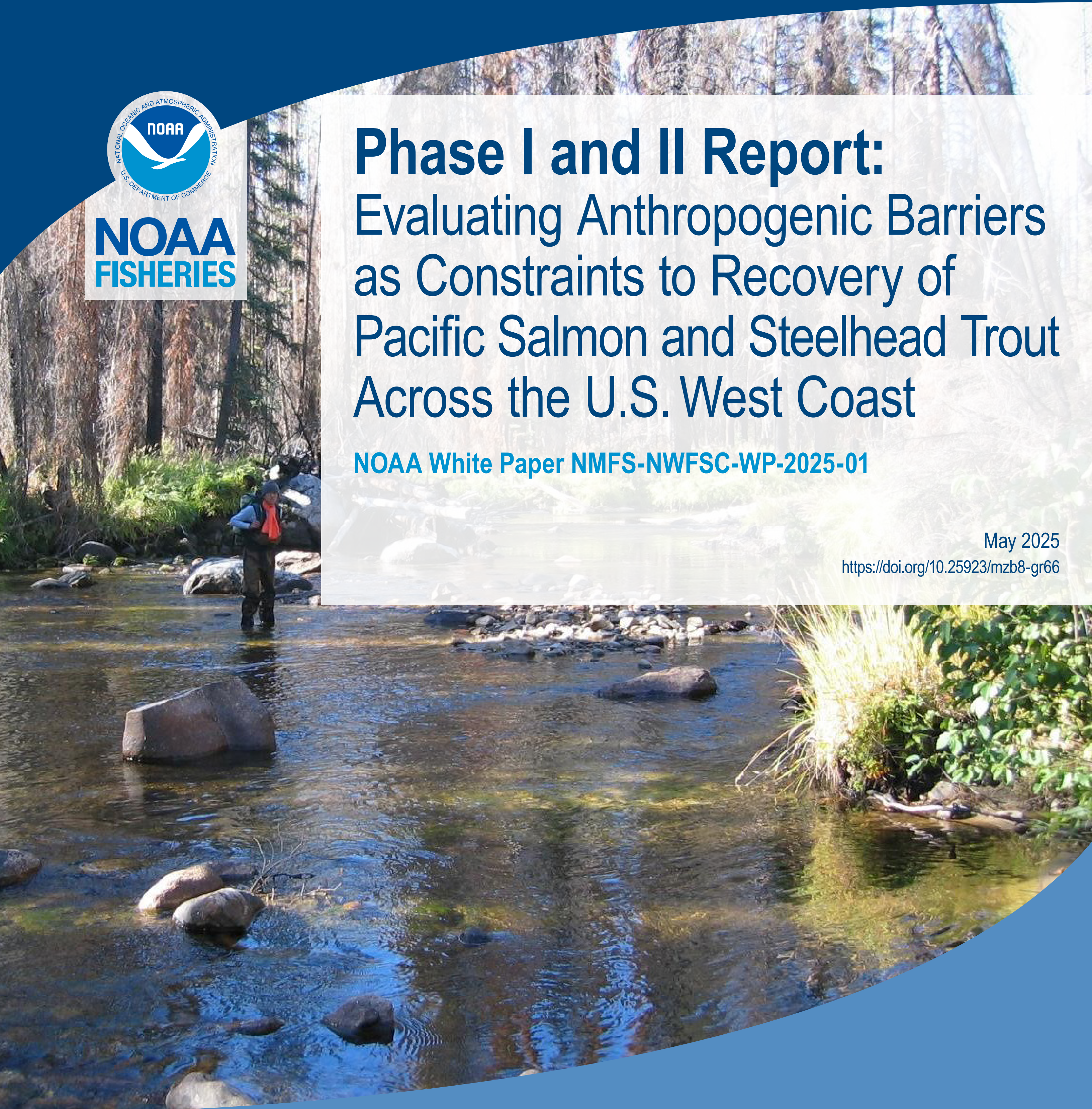

Phase I and II Report: Evaluating Anthropogenic Barriers as Constraints to Recovery of Pacific Salmon and Steelhead Trout Across the U.S. West Coast

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May 2025
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Cover image: Chamberlain Creek, Idaho, home of ESA-listed Snake River Chinook salmon and steelhead trout. Photograph by P. Kiffney, NMFS/NWFSC.

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https://doi.org/10.25923/mzb8-gr66

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May 2025

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Plain Language Summary

The aim of the project is to identify human-caused (anthropogenic) barriers—mostly dams—that, according to the evidence, restrict the recovery of populations of Pacific salmon and steelhead (salmonids) listed as either threatened or endangered under the Endangered Species Act of 1973. This report focuses on their range along the U.S. West Coast (Washington, Idaho, Oregon, and California).

We summarize methods and results for Phase I (data collection) and introduce an approach for Phase II (data verification) of a four phase project to prioritize fish passage for listed salmonids, with a goal of increasing population resilience. Phases III and IV will model habitat quality above problematic barriers to estimate how, at a population level, these fish might respond to being reintroduced into these areas.

In Phase I, we reviewed recovery plans and five-year status reviews led by NOAA Fisheries for each evolutionarily significant unit (ESU[1]) or distinct population segment (DPS[2]) of ESA-listed Pacific salmon and steelhead trout, to determine whether these reports identified dams and other barriers as significant concerns for population recovery. In addition, we reviewed the climate vulnerability of each population within the context of fish passage.

In Phase II, we were tasked to collect feedback from experts who have specific local knowledge of an ESU/DPS to see whether the reports missed dams or environmental conditions that might slow recovery. To address these questions, we worked with database specialists at NWFSC to design an online app for experts to provide data on each ESU/DPS, in addition to helping our data analysis and summarization. The app also allows experts to identify key dams/barriers or environmental concerns that are not included in our database.

Links used in this section:

- Pacific salmon and steelhead: https://www.fisheries.noaa.gov/species/pacific-salmon-and-steelhead
- Endangered Species Act of 1973: https://www.fisheries.noaa.gov/national/endangered-species-conservation/endangered-species-act
- Fish passage: https://www.fisheries.noaa.gov/west-coast/habitat-conservation/west-coast-fish-passage-guidelines
- Reintroduced: https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/species-reintroductions-west-coast
- Climate vulnerability: https://www.fisheries.noaa.gov/west-coast/climate/pacific-salmon-climate-vulnerability

[1] An ESU is a population that is substantially reproductively isolated from other populations of the same species and represents an important component in the evolutionary legacy of the species.
[2] A DPS represents the smallest division of a taxonomic species protected under the ESA. Criteria used to identify a DPS are conditions that promote and maintain distinctness from other populations of the same species due to physical, physiological, ecological, or behavioral factors.

Introduction

As a result of a variety of anthropogenic changes, including installation of migratory barriers such as dams and culverts, there are 28 ESA-listed threatened and endangered evolutionary significant units (ESUs) or distinct population segments (DPSes) of Pacific salmon and steelhead trout (11 steelhead trout, nine Chinook salmon, four coho salmon, two chum salmon, and two sockeye salmon). Many of these barriers block access to high-elevation, cold-water habitat. Restoring access to these historic cold-water habitats may be particularly important in increasing the resilience of ESA-listed populations of salmon and steelhead to climate warming. Thus, there is a need for basic information, such as the amount and quality of habitat blocked by the barrier, that can be used to decide which barrier(s) to circumvent, either through removal or fish passage, that would increase populations' resilience to a changing climate.

In this report, we present results and updates from Phases I and II of a collaborative project to prioritize dam removal across the west coast region (Washington, Idaho, Oregon, and California) consisting of several line offices in the National Marine Fisheries Service (NMFS), including the Northwest Fisheries Science Center (NWFSC), the West Coast Regional Office (WCR), and the Restoration Center (RC). The original project proposal was developed by Steve Edmondson (formerly WCR), George Pess (formerly NWFSC), Tim Beechie (formerly NWFSC), Leah Tolley (RC), and John Floberg (formerly RC).

To provide context for this report, the project title, purpose, goals, objectives, deliverables, and Phase I and II tasks from the proposal are presented in Section 1, where we briefly summarize next steps with Phase II (in progress), III, and IV (projected) tasks.

The report comprises the following six sections:

1. Information from the project proposal, outlining tasks associated with Phases I and II (the focus of this report) and next steps for Phases III and IV.
2. Data collection methods for Phase I.
3. Results for Phase I.
4. Proposed methodology for Phase II, the data verification phase.
5. Results to date for Phase II.
6. Next steps.

1. Project Proposal Outline

Project Title: Assessing Fish Passage Opportunities Across the WCR for Recovery Benefit.

Project Purpose: To improve our effectiveness in prioritizing fish passage, create partnerships, and gain necessary support from stakeholder groups, NMFS' WCR Hydro Program and NMFS' Community-based Restoration Program are collaborating with NWFSC on an effort to identify fish passage actions that are most likely to contribute to recovery of all ESUs/DPSes and associated populations across the West Coast Region. The work is a multi-phase effort that has been underway since 2022. Throughout the historically anadromous rivers of the U.S. West Coast, hundreds of thousands of anthropogenic barriers fully or partially block upstream access by migrating salmon. Many small barriers (e.g., culverts, road crossings) are unassessed for blocking status, particularly on smaller streams. Our coastwide effort focuses on dams that block substantial amounts of habitat, such that removal or passage would provide a significant benefit for the population and ESU.

Goal: Maximize the increase in viable salmonid population (VSP) parameters of listed salmonids.

Project Objectives:

- Identify ESUs and/or populations for which barriers are a significant issue.
- Identify barriers with the greatest potential for population improvement with respect to VSP criteria.

Phase I Tasks—Completed

Review NMFS recovery products (i.e., recovery plans, five-year status reviews) and NOAA's analysis of salmon vulnerability to climate change (Crozier et al. 2019) and present the following information for each ESU/DPS:

- All populations associated with a potential barrier.
- Role of populations in ESU (core, independent, etc.).
- Factors limiting the status of each ESU/DPS and individual population.
- Note any mention of specific barriers—their type, severity, and location.
- Include references to information.

Phase II Tasks—Ongoing

For each ESU, WCR and RC will identify a Species Contact who will coordinate within NMFS as appropriate (e.g., with relevant NMFS personnel such as Branch Leads, WCR's Federal Energy Regulatory Commission Team, RC field staff, and Science Center area experts) and ask them to:

- Review and verify information collected for the ESU; suggest changes as necessary.
- Identify *significant* barriers missing or not specifically named in the recovery inventory.
- Identify other factors that should be considered when thinking about the potential of barrier removal to improve populations.

Phase III and IV Tasks—Future

In Phase III, we will assess the intrinsic habitat potential (IP) for the adult life stage of salmon and steelhead above priority dams/barriers identified in Phases I and II.

In Phase IV, based on the IP analysis, we will identify a list of high-priority barriers across the West Coast Region (Washington, Idaho, Oregon, and California) that, if barrier removal/fish passage occurs, have the potential to improve VSP parameters for a particular ESU/DPS in the face of climate change. We will also consider doing a couple of pilot areas, e.g., for the California Central Valley.

2. Phase I—Data Collection Methods

The schematic in Figure 1 provides a workflow diagram for this project, including completed tasks (blue), tasks close to completion (red), and tasks in progress or to be completed (black).

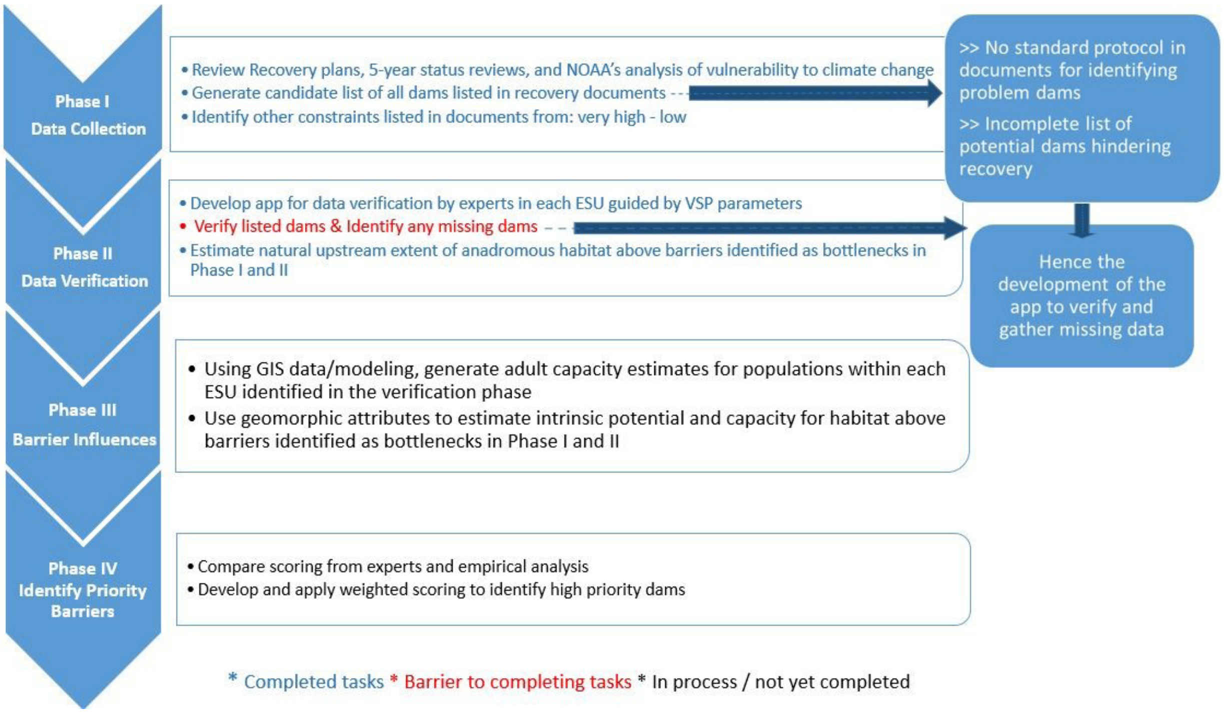

Figure 1. Schematic describing project workflow.

2.1 Identifying Key Dams from NMFS Documents

In Phase I, we searched NMFS recovery plans and five-year status reviews for 28 ESA-listed U.S. West Coast Pacific salmon and steelhead trout evolutionarily significant units (ESUs) or distinct population segments (DPSes) using the following keywords: *dam*, *dam removal*, *barrier*, *barrier removal*, *migratory barrier*, and *fish passage*.

Table 1 provides a list of reviewed NMFS recovery plans and 5-year status reports available for each ESU/DPS. Table 1 includes hyperlinks for each document reviewed.

For each ESU/DPS, we noted the page number and summarized text where a dam, artificial barrier, and/or fish passage was mentioned as a significant roadblock for recovery. If provided, we also noted severity, type, and location of the barrier, and population(s) affected (see Section 3).[1] Because of the large number of anthropogenic barriers in the region, we focused on large dams identified in the National Inventory of Dams that block or impede passage to more than 10 km^2 of catchment area, for two reasons.[2] First,

1 All page numbers (e.g., *p. 7*) refer to the location of the relevant text in recovry plans, except when noted.
2 https://nid.sec.usace.army.mil/#/

Table 1. List of reviewed NMFS recovery plans and five-year status reviews available for each ESU/DPS. This list includes hyperlinks for each document reviewed (click year).

Species	ESU/DPS	Recovery Plan	5-Year Status Review(s)
Chinook salmon	Sacramento River winter run	2014	2016, 2024
	Central Valley spring run	2014	2016
	California Coastal	2016	2016
	Upper Willamette River	2011	2016
	Snake River spring/summer	2017	2016, 2022
	Snake River fall run	2017	2016, 2022
	Upper Columbia River spring run	2007	2016, 2022
	Lower Columbia River	2013	2016, 2022
	Puget Sound	2007	2016
Coho salmon	Central California Coast	2012	2016, 2023
	Southern Oregon/Northern California Coastal	2014	2016
	Oregon Coast	2016	2016, 2022
	Lower Columbia River	2013	2016, 2022
Chum salmon	Columbia River	2013	2016, 2022
	Hood Canal summer run	2005	2016
Sockeye salmon	Snake River	2015	2016, 2022
	Ozette Lake	2009	2016, 2022
Steelhead trout	Southern California Coast	2012	2016, 2023
	South Central California Coast	2013	2016, 2023
	California Central Valley	2014	2016
	California Central Coast	2016	2016
	Northern California	2016	2016
	Lower Columbia River	2013	2016, 2022
	Upper Willamette River	2011	2016
	Middle Columbia River	2009	2016, 2022
	Snake River	2017	2016, 2022
	Upper Columbia River	2007	2016, 2022
	Puget Sound	2019	2016

evaluating the presence of anthropogenic barriers in catchment areas smaller than 10 km^2 results in an extraordinarily large number of barriers within each ESU/DPS, making it challenging to identify specific barriers. Second, there is evidence that this catchment size approximates a potential breakpoint for the upstream distribution of anadromous salmonids (Buehrens et al. 2013, Ptolemy 2013).

The conservation success of barrier circumvention—whether it be transportation, dam removal, or fish ladders—on listed populations will depend, in part, on aquatic habitat conditions above and below the barrier, such as connectivity and thermal regime. Therefore, we also examined whether the reviewed documents mentioned other environmental stressors (e.g., water temperature) that are or may be constraints on ESU/DPS recovery. In a conservation context, deciding which anthropogenic barriers to circumvent will partly depend on the amount of high-quality habitat above and below the barrier.

To identify other environmental factors that might modify the success of barrier circumvention, we searched for the following keywords: *water temperature*, *thermal regime*, *sediment*, *sedimentation*, *siltation*, *contaminants*, *chemicals*, *pollutants*, *toxins*, *flow*, *discharge*, *connectivity*, *habitat simplification*, *habitat complexity*, *channelization*, and *invasive species*. For each document, we note the page number and describe the habitat-related limiting factor(s) identified as actual or potential constraints for ESU/DPS recovery.

Ideally, the documents would have explicitly identified the importance of other environmental stressors to the recovery of an ESU/DPS, including the population units most affected, within the context of barrier circumvention. Unfortunately, we did not find such information. This is not surprising given the costs in collecting the data necessary to achieve the appropriate ecological knowledge. We anticipate that some of this information will be provided by local experts in Phase II, the data verification phase.

To characterize the relative importance of dams as constraints on the recovery of an ESU/DPS, we used the following scale:

1. An ESU was ranked *very high* in its sensitivity if specific dams (e.g., Scott Dam on the Eel River) or other anthropogenic barriers were named where barrier circumvention was required to recover the ESU.
2. We ranked an ESU as *high* if dams or other anthropogenic barriers were identified as a limiting factor, but specific details on the scale or import of the impact were not provided.
3. We ranked an ESU as *moderate* if dams or other anthropogenic barriers were identified as a concern, but not a primary factor.
4. We ranked an ESU as *low* if dams or other anthropogenic barriers were mentioned, but not in the context of ESU/DPS recovery.
5. If dams or other anthropogenic barriers were not mentioned as a limiting factor, we assigned “not mentioned” (*NM*) to the ESU.

In order to provide information on the climate change threats predicted to affect an ESU/DPS, we report on rankings from the climate vulnerability assessment conducted by Crozier et al. (2019). The authors used an expert-based qualitative scoring system (overall sensitivity or exposure: 1 = low, 2 = moderate, 3 = high, and 4 = very high) to evaluate all anadromous Pacific salmon and steelhead population units listed under the ESA with respect to biological sensitivity, or the strength of linkages between each listing unit and the present climate; climate exposure, or the magnitude of projected change in local environmental conditions; and adaptive capacity, or the ability to modify phenotypes to cope with new climate conditions.

Note: Almost all Columbia River anadromous salmon and steelhead trout navigate one to several large mainstem dams on their migration to and from the ocean. For example, Snake River sockeye salmon navigate eight Columbia River mainstem dams to reach their spawning grounds, in addition to smaller barriers upstream. Although the Columbia River dams have significantly modified environmental conditions for anadromous fish on the Columbia River, including flow and water temperature, all have some form of fish passage, including ladders or transport by barge/trucks. In addition, these dams are considered key federal infrastructure. As a result, in terms of barrier circumvention, most of the discussion of anthropogenic barriers associated with Columbia River stocks in the reports largely focused on structures upstream of the eight lower mainstem dams and downstream of Chief Joseph and Grand Coulee Dams (which determine the ESU upstream boundary for Chinook salmon and the DPS boundary for steelhead trout).

2.2 Collection of Spatial Data

2.2.1 ESU/DPS boundaries

We compiled spatial boundary information for each U.S. West Coast ESU/DPS listed as threatened or endangered and described in NMFS recovery documents and five-year status reviews (Table 2). We also compiled spatial information for the Central Valley fall/late-fall run because it has been described as a species of concern and was noted in Crozier et al. (2019).[3]

We used a data layer created for McClure et al. (2018) that included all ESUs for salmonids in the West Coast Region. These data were obtained from WCR and include ESUs listed as threatened or endangered. We split and merged by species and ESU to create our ESU boundary layers grouped by species type (Table 1) for a total of 28 boundary layers.

Each ESU boundary polygon layer contains the following information:

State(s): WA, ID, OR, CA, and/or MT.

Species: Chinook salmon, coho salmon, chum salmon, sockeye salmon, and steelhead trout.

ESU: Name of ESU or DPS.

Status: Endangered, threatened, species of concern, or not warranted.

Access status: Accessible, accessible—likely extirpated, or historical watershed: anthropologically blocked.

[3] https://caltrout.org/sos/species-accounts/salmon/chinook-salmon/central-valley-fall-run-chinook-salmon

Table 2. List of ESUs/DPSes grouped by species and color-coded with listing status: endangered (shaded red) or threatened (shaded orange).

	Chinook salmon	Coho salmon	Chum salmon	Sockeye salmon	Steelhead trout
ESU/DPS	Sacramento River winter run	Central California Coast	Columbia River	Snake River	Southern California Coast
	Central Valley spring run	Southern Oregon/Northern California Coastal	Hood Canal	Ozette Lake	South Central California Coast
	California Coastal	Oregon Coast			California Central Valley
	Upper Willamette River	Lower Columbia River			California Central Coast
	Snake River spring/summer run				Northern California
	Snake River fall run				Lower Columbia River
	Upper Columbia River spring run				Upper Willamette River
	Lower Columbia River				Middle Columbia River
	Puget Sound				Snake River
					Upper Columbia River
					Puget Sound

2.2.2 U.S. West Coast dam layers

We evaluated a number of datasets that contained dam point layers for each state in the West Coast Region, including the U.S. Army Corps of Engineers National Inventory of Dams (NID), the U.S. Geological Survey Dam Removal Information Portal (DRIP) dataset, the California Cooperative Anadromous Fish and Habitat Data Program's (CalFish) Passage Assessment Database (PAD), the U.S. Department of Energy's Existing Hydropower Assets (EHA) Plant database, and the Southeast Aquatic Resources Partnership's (SARP) Aquatic Barrier Inventory dataset. In the end, we found SARP's by-state inventory to be the most up-to-date and comprehensive dataset that contained the attribute data we needed.[4]

We use dam point layers for two purposes: 1) as a dataset to visualize for expert verification for our app (project Phase II), and 2) for our intrinsic potential (IP) analysis (project Phase III). For the expert verification step, we wanted to limit the noise of too many dams on the map presented to experts, so we limited the

[4] NID: https://nid.sec.usace.army.mil/; DRIP: https://data.usgs.gov/drip-dashboard/; PAD: https://www.calfish.org/ProgramsData/HabitatandBarriers/CaliforniaFishPassageAssessmentDatabase.aspx; EHA: https://hydrosource.ornl.gov/; SARP: https://aquaticbarriers.org/.

point layer to dams located on a network with a drainage area of 10 km^2 or greater. As noted previously, this catchment size also coincides with a potential breakpoint for the upstream extent of anadromous salmonids along the U.S. West Coast (e.g., Buehrens et al. 2013). We assumed that most dams identified as problematic would fall within this limitation and, if not, that local experts are able to fill in any missing dams. For the IP analysis, we will not apply this ≥10 km^2 filter and we will add any additional dams identified by experts, as appropriate and confirmed ,that were not listed in the recovery plans and five-year status reviews.

We downloaded "dam-only" point data for each state (WA, ID, MT, OR, NV, CA) from the SARP website. After converting these data into point layers, we merged the individual states' data into one point layer, then clipped it by Water Resource Inventory Area (WRIA) 17 and 18 boundaries. SARP dam points came with attribute data related to the National Hydrography Dataset (NHD) network; however, some dams of interest were either not clipped to the NHD network or clipped to the incorrect network feature. To correct for this, we worked closely with SARP contacts who continue to improve and update their dam and barrier point layers. We added an attribute to the point layer to identify dams that were specifically mentioned in recovery plan documents, five-year status reviews, or expert contacts. We labeled this column as "recovery listed dams".

Some of the maps presented below show dams identified in NMFS recovery plans and five-year status reviews (represented by red squares) that are not discussed in the text. This is because we have one spatial data layer with all listed dams together, and it is displayed on all maps, so if a dam is listed for another population within the same geographic area, it will appear on all maps of that area.

3. Phase I—Results

We constructed maps for each ESU showing all dams blocking greater than 10 km^2 and dams identified in recovery documents. Maps show currently accessible habitat; accessible habitat, but the population is likely extirpated; and historically accessible habitat blocked by dams.

In the maps, dams blocking greater than 10 km^2 are depicted as maroon circles; dams depicted as red squares were identified in NMFS recovery documents as potential constraints to population recovery. Table 3 presents a number key to dams identified in the recovery documents and as depicted on the maps.

Table 3. Key to recovery listed dams identified in the recovery documents and depicted on the maps throughout the results section.

Name	Dam ID
Anthony House Dam	1
Big Cliff Dam	2
Black Butte Dam	3
Bonneville Locks and Dam	4
Bradbury Dam	5
Brownlee Dam	6
Bumping Lake Dam	7
CA Water Service Dam (Diversion Dam #15)	8
Camanche Dam	9
Camp Far West Dam	10
Cape Horn Dam	11
Casitas Dam	12
Cle Elum Dike 1	13
Clear Branch Dam	14
Cogswell Dam	15
Coyote Valley Dam	16
Crocker Diversion Dam	17
Del Valle Dam	18
Detroit Dam	19
Diablo Dam	20
Dworshak Dam	21
Fall Creek Dam	22
Feather River Improvement	23
Folsom Dam	24
Foster Dam	25
Gibraltar Dam	26
Goodwin Dam	27
Gorge Dam	28
Grand Coulee Dam	29
Green Peter Dam	30
Harry L. Englebright Dam	31
Harvey Dam (Santa Paula Diversion)	32
Hells Canyon Dam	33
Hills Creek Dam	34
James H. Turner Dam	35
John Day Lock and Dam	36
Juncal Dam	37
Kachess Dam	38
Keechelus Dam	39
Keswick Dam	40
La Grange Dam	41
Lookout Point Dam	42
Lower Baker Dam	43
Lower Bennett Diversion Dam	44
Malibou Lake Club Dam	45
Matilija Dam	46
McNary Lock and Dam (Richland Levee 4A)	47
Nacimiento Dam	48
New Calaveras Dam	49
New Don Pedro Dam	50
New Exchequer Dam	51
New Hogan Dam	52
New Melones Dam	53
Nimbus Dam	54
Nursery Bridge Dam	55
Oxbow Dam	56
Pelton Dam	57
Priest Rapids Dam	58
Pyramid Dam	59
R. W. Matthews Dam	60
Red Bluff Diversion Dam	61
Rindge Dam	62
Robles Diversion Dam and Downstream Weir	63
Rock Island Dam	64

Table 3 (continued). Key to recovery listed dams identified in the recovery documents and depicted on the maps throughout the results section.

Name	Dam ID
Rocky Reach Dam	65
Ross Dam	66
San Antonio Dam	67
San Gabriel Dam	68
Santa Fe Dam	69
Santa Felicia Dam	70
Scott Dam	71
Searsville Dam	72
Shasta Dam	73
Swan Falls Dam	74
The Dalles Lock and Dam	75
Tieton Dam	76
Trinity Dam	77
Twitchell Dam	78
Upper Baker Dam	79
Upper Bennett Diversion Dam	80
Vern Freeman Diversion Dam	81
Virginia Ranch Dam	82
Wanapum Dam	83
Warm Springs Dam	84
Wells Dam	85
Wenas Dam	86
Whiskeytown Dam	87
William L. Jess Dam (Lost Creek Lake Fish Structure)	88

3.1 Chinook Salmon (*Oncorhynchus tshawytscha*)

3.1.1 Central Valley recovery domain

Sacramento River winter run

Status: Endangered

Artificial barriers limiting factor: Very high

Adaptive capacity: Low

Population viability sensitivity: High

Hatchery influences: Moderate

Sensitivity to extrinsic factors: Very high

Overall vulnerability: Very high

Comments: The range of the winter-run Chinook salmon population in the Sacramento River (Figure 2) has been severely diminished by Keswick and Shasta Dams, hydroelectric development on Battle Creek, Anderson-Cottwood Irrigation Districts diversion dam, and culverts, railway crossings, etc. (p. 21).[5] An estimated 1,812 km (1,126 mi) of stream remain of the more than 3,513 km (2,183 mi) of Central

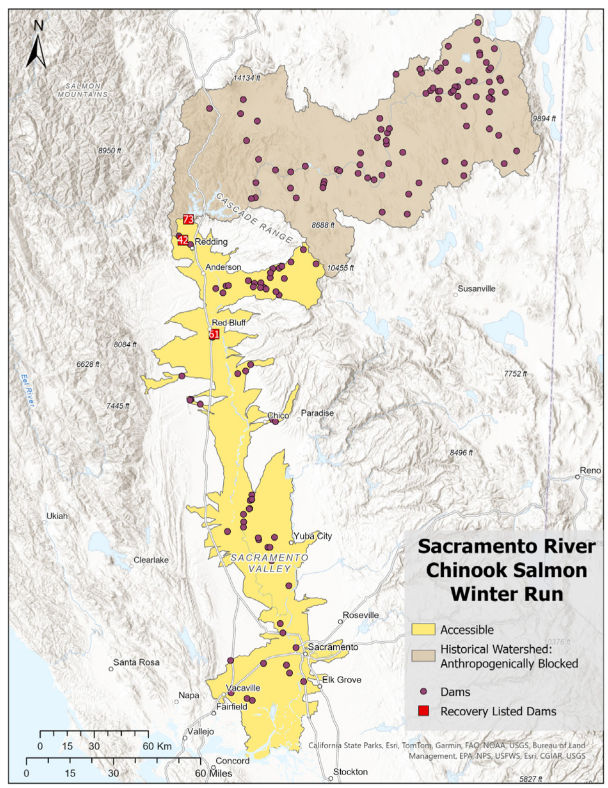

Figure 2. Map of the Sacramento River Chinook salmon winter run.

[5] Page numnbers throughout refer to the associated recovery plans (see Table 1) unless otherwise noted.

Valley streams that were historically accessible by Chinook salmon—indicating an overall loss of at least 1,701 km (1,057 mi), or 48% of the original total.

Many dams and other artificial barriers block access to high-elevation, cool-water stream systems, which are essential habitat needed to increase the resilience of this ESU to changes caused by climate change. As a result, there are major efforts underway or in planning to remove barriers and to reintroduce Chinook salmon above dams that block upstream migration, including above Shasta Dam into the McCloud River and the Coleman Barrier Weir Dam (p. 83).

There are multiple other threats to this ESU, including: increased summer temperatures, especially in dry years when water storage in Shasta Reservoir is limited; altered flow regime; habitat modification and simplification; loss of floodplain habitat; historical mining and logging operations; logging, agricultural, and mine runoff; predation by non-native fish; and a highly modified estuary in the Sacramento–San Joaquin Delta (pp. 11, 13, 21, 44–45).

Central Valley spring run

Status: Threatened

Artificial barriers limiting factor: Very high

Adaptive capacity: Low

Population viability sensitivity: High

Hatchery influences: Very high

Sensitivity to extrinsic factors: Very high

Overall vulnerability: Very high

Comments: Loss of access to historical habitat by the construction of dams and other artificial barriers is one of the main reasons Central Valley spring-run Chinook salmon (Figure 3) are an ESA-listed species (p. 40). Historical accounts suggest spring-run Chinook salmon were separated from the fall run by upstream extent and timing. Reportedly, spring-run Chinook salmon migrated to the upper Feather River and its tributaries from mid-March through the end of July. Fall-run Chinook salmon reportedly migrated later and spawned in lower reaches of the Feather River than the spring run.

The loss of habitat connectivity remains an important threat to recovery of this ESU, as most of the historical habitat continues

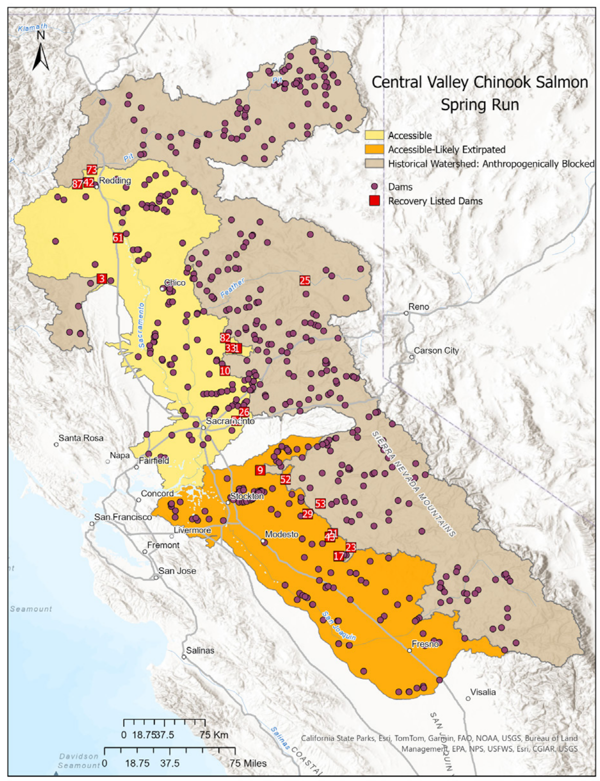

Figure 3. Map of the Central Valley Chinook salmon spring run.

to be blocked. The construction of dams in the Central Valley has eliminated virtually all access to the historical spawning habitat of spring-run Chinook salmon in the basin (p. 40). Dams block access to 80% of all historically available habitat and over

90% of historically available spawning and rearing habitat, and block access to historical spawning habitat for about 38% of the historical populations (p. 55). Much of the habitat upstream of the rim dams remains in relatively good condition and is located on lands managed by the National Park Service, U.S. Forest Service, and Bureau of Land Management.

Twelve large dams currently act as migratory barriers to anadromous salmonids (p. 48, their Figure 2-9), in addition to the thousands of small dams, culverts, road crossings, and inadequately screened water diversions. Some of the large dams include Keswick Dam and Red Bluff Diversion in the north of the range, Nimbus Dam in the center, and Crocker Diversion in the south. Meeting recovery objectives for redundancy and distribution will require reintroducing some populations to habitats that historically supported the species but are currently inaccessible due to existing dams (p. 79).

There are multiple other threats to this ESU, including: increased summer temperatures, especially in dry years; altered flow regime; habitat modification and simplification; loss of floodplain habitat; historical mining operations; agricultural and mine runoff; predation by non-native fish; and a highly modified estuary in the Sacramento–San Joaquin Delta (pp. 11, 13, 21, 44–45, and elsewhere).

Note: When the recovery plan was written, it was assumed that the San Joaquin River population was extinct and, therefore, no specific recovery actions were recommended for key tributaries to the San Joaquin River aside from implementation of the San Joaquin River Restoration Program downstream of Friant Dam (J. Ambrose, NMFS WCR, personal communication).

3.1.2 North-Central California recovery domain

California Coastal

Status: Threatened

Artificial barriers limiting factor: Low–moderate

Adaptive capacity: Low

Population viability sensitivity: High

Hatchery influences: Low

Sensitivity to extrinsic factors: High

Overall vulnerability: Very high

Comments: Scott Dam blocks passage to approximately 58 km (35.7 mi) of Chinook salmon spawning and rearing habitat in the upper mainstem Eel River (Figure 4). Passage at this facility would provide habitat for an estimated 1,200 spawning adults and provide additional viability for the Upper Eel River Chinook salmon population (p. 312). FitzGerald et al. (2022) estimated a range of 51 km (31.7 mi) to 129 km (80.51 mi) in a warm year.

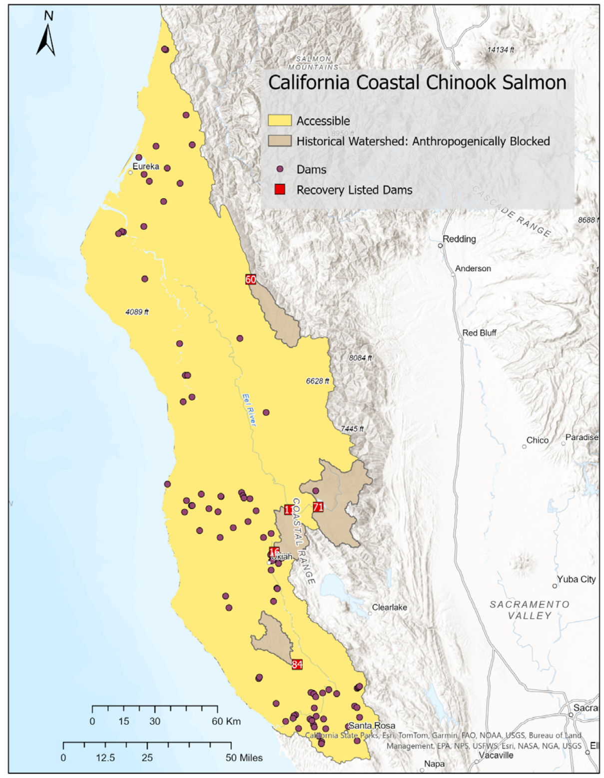

Figure 4. Map of the California Coastal Chinook salmon ESU.

PGE recently announced plans to remove both Scott and Cape Horn Dams on the Eel River as part of its license surrender and decommissioning of the Potter Valley Project.[6]

Multiple other threats affect this ESU. Many large rivers and streams are listed by the EPA as impaired by water temperature and sediment pollution (p. 16). For example, the Mattole (p. 229) and Mad (p. 207) Rivers are listed as water temperature impaired by the EPA. Plus, this ESU is impacted by large-scale changes from past human activities, including logging, and current activities, including water diversions (p. 16). This ESU is also threatened by altered stream flows, such as low flows during the summer, and loss of large wood debris (LWD), habitat complexity, and floodplain connectivity.

[6] https://caltrout.org/news/eel-river-dams-headed-for-removal-water-users-support-dam-free-diversion

3.1.3 Willamette/Lower Columbia recovery domain

Upper Willamette River

Status: Threatened

Artificial barriers limiting factor: Very high

Adaptive capacity: Moderate

Population viability sensitivity: Very high

Hatchery influences: Very high

Sensitivity to extrinsic factors: High

Overall vulnerability: Very high

Comments: All populations are affected by hydropower facilities, resulting in a loss of historic production (p. 6-11). Detroit and Big Cliff Dams on the North Santiam River are complete barriers to upstream adult migration, blocking access to an estimated 71% of the historical production area for Chinook salmon. Upper Bennett (RM 31.5) and Lower Bennett Dams (RM 29) impair adult spring Chinook salmon access to habitat upstream of the dams. Green Peter and Foster Dams block or limit access to an estimated 85% of the historical production area for Chinook salmon on the South Santiam River. Both dams have passage provisions of varying efficiencies. Current access to above-dam habitat is provided with trap-and-haul methods for adults, while outmigrating juveniles in the spring swim through penstocks, spillways, and a newly constructed weir.

Access remains blocked to more than half of the stream length historically accessible to Chinook salmon for the Calapooia River population (p. 5-63).The dams and diversions within the Thompson's Mill complex (RM 19.5–28.5) have the greatest impact on fish passage. While Sodom Dam is equipped with a fish ladder, migrating Chinook salmon are delayed at the base of the dam, which subjects them to additional stress and possible harassment and poaching (p. 5-63).

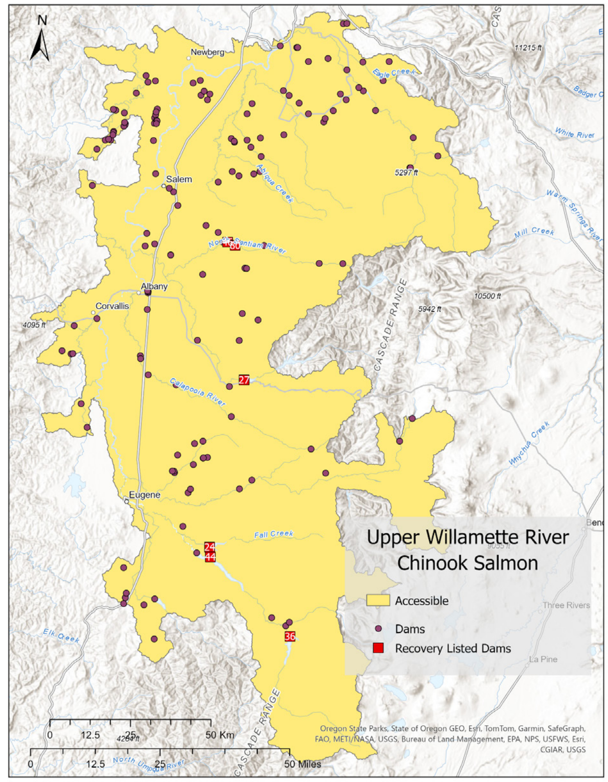

Figure 5. Map of the Upper Willamette River Chinook salmon ESU.

Eighty-four percent of total historic intrinsic potential for Chinook salmon would be available for production with adult access actions above Lookout Point, Falls Creek, and Hills Creek Dams on the Middle Fork of the Willamette River (p. 6-17).

Dams and diversions limit fish migration and recovery for several other independent populations in this ESU. There are several fish transfer programs in operation; however, the success of these activities is unclear.

Other threats to this ESU include the effects of dam operations on river and riparian habitats within the dam's footprint, including: altered flows, temperature, nutrient fluxes, and biotic structure, interactions, and function; loss of habitat structure, complexity, and floodplain connectivity; loss and contamination of estuarine habitat; contamination of mainstem habitat near urban centers (p. 5-10); and predation by non-natives (p. 5-9).

3.1.4 Interior Columbia recovery domain

Snake River spring/summer run

Status: Threatened

Artificial barriers limiting factor: Very high

Adaptive capacity: Moderate

Population viability sensitivity: NM

Hatchery influences: Moderate

Sensitivity to extrinsic factors: High

Overall vulnerability: Very high

Comments: This ESU lost access to large blocks of its historical habitat on both the mainstem and tributaries (Figure 6). Furthermore, dams block access to some of the historically most productive habitats (p. 26 and p. 72, their Figure 2-6). Dams block an estimated 338 km (210 mi) of historic habitat in the mainstem Snake River above Hells Canyon Dam and hundreds of additional miles of tributary habitat for this ESU (p. 149). Dworshak Dam led to the extirpation of Chinook salmon and other anadromous fish in the North Fork Clearwater River basin.

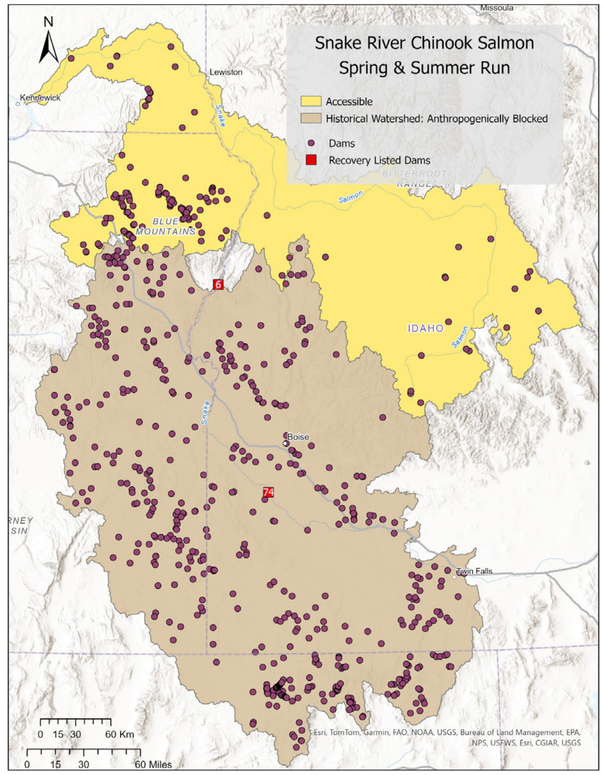

Figure 6. Map of the Snake River Chinook salmon spring/summer run.

A majority of the land base for this ESU consists of federally managed forests and grasslands or wilderness areas and is thus of relatively high quality for salmonids overall. However, portions of the ESU that are not on protected lands are degraded by loss and simplification of stream, riparian, and floodplain habitats resulting from current and past land use activities, such as logging, grazing, agriculture, and mining (p. 131). Table 5-3 in the recovery document identifies a list of widespread limiting factors in tributary habitats and populations affected by each factor (pp. 134–135).

Snake River fall run

Status: Threatened

Artificial barriers limiting factor: Very high

Adaptive capacity: High

Population viability sensitivity: NM

Hatchery influences: High

Sensitivity to extrinsic factors: High

Overall vulnerability: Very high

Comments: Dams in the Snake River (Figure 7) block access to some of the historically most productive habitats (p. 49, their Figure 1.1, and p. 168). Dams block access to an estimated 338 km (210 mi) of historic habitat in the mainstem Snake River above Hells Canyon Dam and hundreds of additional miles of tributary habitat for this ESU (p. 149). Dworshak Dam extirpated Chinook salmon in the North Fork Clearwater basin.

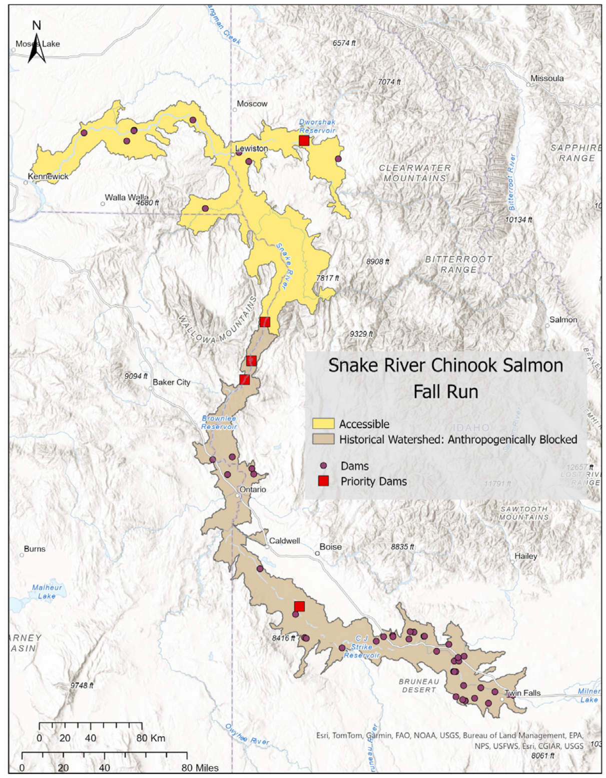

Figure 7. Map of Snake River Chinook salmon fall run ESU.

This ESU is impacted by multiple other environmental threats. Some portions of the middle Snake River upstream of the Hells Canyon Complex are blocked to this ESU due to degraded conditions by high water temperatures, excessive nutrients and algae, and anoxic or hypoxic conditions (pp. 36–37). River habitat below dams is highly modified by altered flow, sediment, organic matter, and nutrient regimes resulting from dam operations (pp. 37–38). Estuarine conditions are also highly modified due to habitat loss and modification (p. 38).

Upper Columbia River spring run

Status: Endangered

Artificial barriers limiting factor: Low

Adaptive capacity: Moderate

Population viability sensitivity: High

Hatchery influences: High

Sensitivity to extrinsic factors: High

Overall vulnerability: High

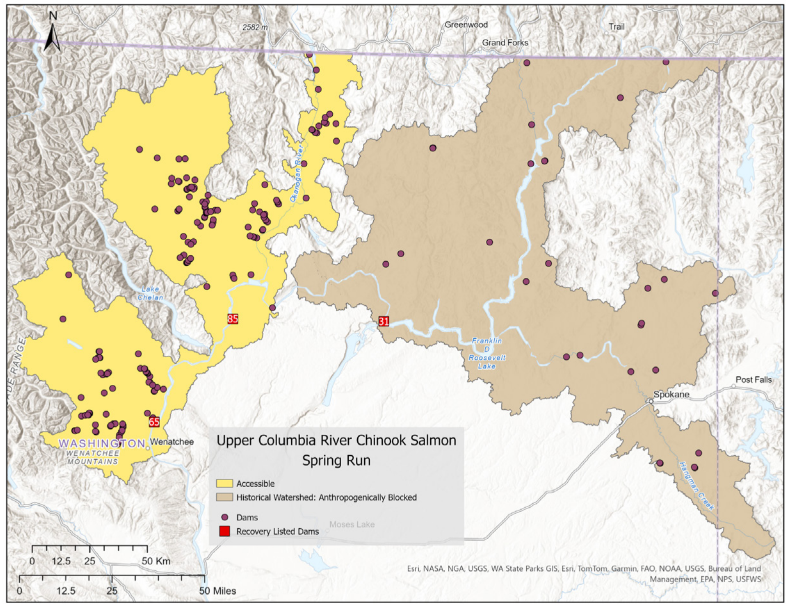

Figure 8. Map of Upper Columbia River Chinook salmon spring run ESU.

Comments: While it did not consider dams and barriers to be a key threat to recovery, the 2016 Upper Columbia River salmon and steelhead five-year status review (SR p. 31[7]) identified the existence and operation of dams in the mainstem migration corridor as threats to the survival and recovery of the spring-run Chinook salmon ESU and steelhead DPS (Figure 8). These include Grand Coulee and Chief Joseph Dams, which block passage to some of the species' historical spawning areas, and nine run-of-the-river dams that reduce the survival of juvenile and adult salmonids compared to a free-flowing reach.

Additional threats include hydroelectric operations of downstream mainstem dams which alter flow, sediment, organic matter, and nutrient regimes, leading to changes in habitat quantity and quality for rearing, holding, and migration. For example, the recovery plan indicated that hydroelectric operations along the mainstem have created pockets of high water temperatures, impacting habitat quality for all life stages (p. 186).

Although habitat conditions have improved in this ESU over the past several years, diversions, road crossings, agriculture, residential development, and historic forest management continue to impact habitat through changes in a variety of factors and processes, including hydrology, water temperature, and sediment and organic matter fluxes (pp. 99–101).

[7] *SR* before a page number indicates that the reference is to a status review, not a recovery plan.

Lower Columbia River

Status: Threatened

Artificial barriers limiting factor: Low

Adaptive capacity: High

Population viability sensitivity: Moderate

Hatchery influences: High

Sensitivity to extrinsic factors: NM

Overall vulnerability: Moderate

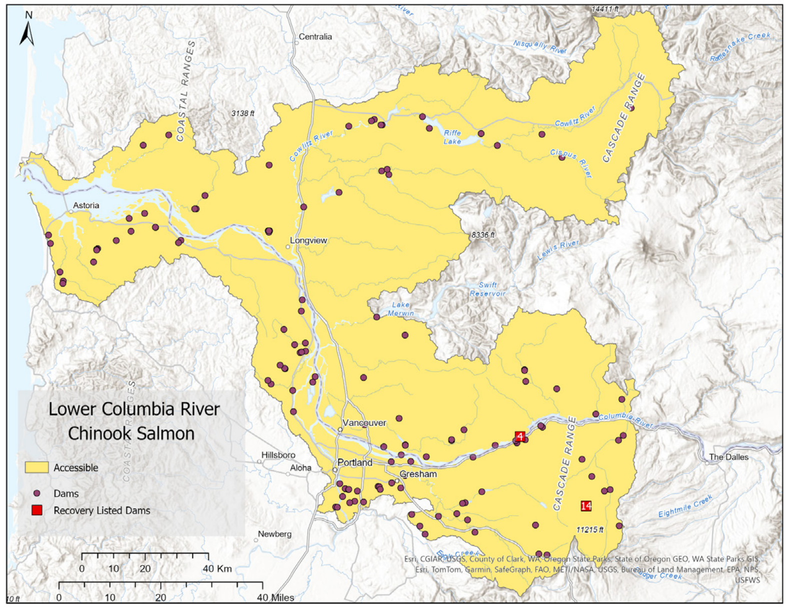

Figure 9. Map of Lower Columbia River Chinook salmon ESU.

Comments: Dams/barriers not considered a key threat to recovery (Figure 9). However, this ESU is affected by a variety of other threats resulting from historic and current land management activities including warmer water temperatures, altered flow regimes, and loss and modification of habitat, especially in the lower Columbia River and estuary (pp. 3-8–3-9).

In addition, dams and reservoirs within this ESU have led to major changes in critical habitat due to changes in thermal, flow, sediment, and organic matter regimes (p. 4-10). Contaminants in the estuary may also be limiting to this ESU (p. 4-11).

3.1.5 Puget Sound recovery domain

Puget Sound

Status: Threatened

Artificial barriers limiting factor: Low–moderate

Adaptive capacity: High

Population viability sensitivity: Moderate

Hatchery influences: Moderate

Sensitivity to extrinsic factors: Very high

Overall vulnerability: Moderate

Comments: Dams/barriers were not considered a key threat to recovery in the recovery plan but were mentioned in the 2016 five-year status review (p. 23), including a diversion dam on the Middle Fork Nooksack River, Howard Hansen Dam on the Green River, and Buckley Diversion Dam on the White River (Figure 10). The dam on the Nooksack River has been removed, while a trap–haul approach is in place on the Green and White Rivers to move fish above the dams; however, the effectiveness of these actions is unclear.

This ESU is impacted by a number of other threats. Habitat loss and degradation are particularly severe in and around urban centers, including several EPA superfund sites and migratory bottlenecks (e.g., Ballard Locks, culverts). For example, sediments, water temperatures, and nutrients reach the thresholds of Chinook salmon mortality along portions of the Nooksack River (p. 70).

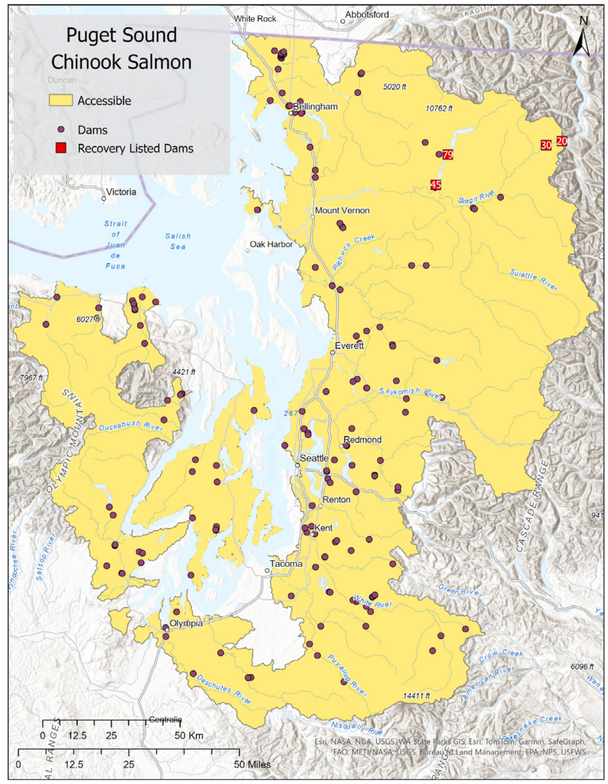

Figure 10. Map of Puget Sound Chinook salmon ESU.

Although some efforts have been made to clean up industrial contaminants, they remain a major threat to this ESU, especially near urban centers like Seattle and Tacoma (p. 72).

Dams also influence riverine habitat for this ESU. The Cedar, Puyallup, and White River populations are affected by altered sediment and flow transport because of dams (p. 282).

3.2 Coho Salmon (*Oncorhynchus kisutch*)

3.2.1 North-Central California recovery domain

Central California Coast

Status: Endangered

Artificial barriers limiting factor: Medium

Adaptive capacity: Low

Population viability sensitivity: Very high

Hatchery influences: low

Sensitivity to extrinsic factors: High

Overall vulnerability: High

Comments: Two large dams were built on the Russian River: Coyote Dam (completed in 1959) and Warm Springs Dam (1982; Figure 11). While these dams pose barriers to other anadromous salmonids, they were probably not significant for coho salmon, as they likely did not spawn in the middle or upper Russian River. However, these dams altered downstream river dynamics by reducing the magnitude of channel-forming winter flows, eliminating replenishment of spawning gravel, and increasing summer flows more than 15 to 20 times above historical levels (p. 36).

Small dams may have the greatest cumulative effect: 500 small dams were counted on key Central California Coast (CCC) coho salmon tributaries of the Russian River in 1996. Besides acting as migration barriers on the lower Russian River's coho salmon streams, these dams reduce spawning gravel and summer water supply downstream (p. 37).

Other threats include impairment of habitat quality. Summer and winter rearing habitat is overall impaired because of reduced LWD, habitat complexity, high sediment loads, high water temperature, low flows, and lack of winter refugia. These conditions worsen from north to south (p. vii).

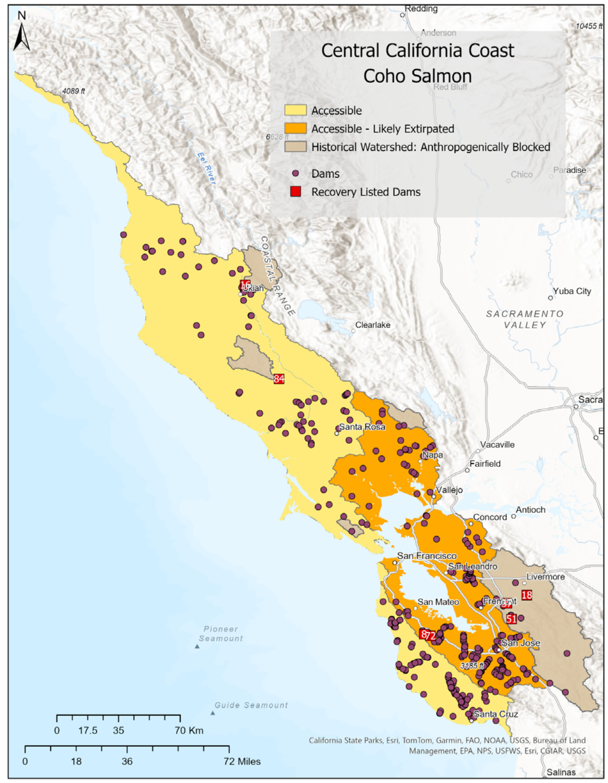

Figure 11. Map of Central California Coast coho salmon ESU.

The 2016 five-year status review noted that the effects of extended drought on water supplies and water temperatures are a major concern for salmonid populations in California. Drought conditions are known to reduce the amount of water available, resulting in reductions (or elimination) of flows needed for adult salmonid passage, egg incubation, and juvenile rearing and migration (SR pp. 14, 28). In addition, the document noted that most major rivers within the ESU remain impaired by high sediment levels, high temperatures, and low dissolved oxygen levels. Unfortunately, many of these legacy effects (i.e., high instream sediment loads, poor LWD recruitment, etc.) continue to impact CCC coho salmon habitat at the present time, and will likely require decades to naturally "heal" as watersheds evolve and respond to altered geomorphic and hydrologic regimes. Conversely, road-related erosion volume, and the impact the resulting sediment has on instream habitat, is a continuing threat that likely remains at a similar level as when the species was listed (pp. 14–16).

To achieve recovery, the plan recommends addressing stream flows, water rights, water temperature, habitat complexity, riparian vegetation, and gravel mining (p. 136).

3.2.2 Southern Oregon/Northern California Coastal recovery domain

Southern Oregon/Northern California Coastal

Status: Threatened

Artificial barriers limiting factor: Very high

Adaptive capacity: High

Population viability sensitivity: Very high

Hatchery influences: NM

Sensitivity to extrinsic factors: Very high

Overall vulnerability: Very high

Comments: Significant improvements to riverine connectivity have been made (e.g., p. 3-30), but fish passage barriers remain an issue. In some ways, anthropogenic barriers restrict the amount of available stream habitat on virtually all Southern Oregon/Northern California Coastal (SONCC) coho salmon rivers (Figure 12) and are listed as a high or very high threat in 13 out of 41 populations (p. 3-29 and their Table 3-4). Approximately 450 man-made barriers remain throughout the California portion of the ESU, blocking access to historical spawning and rearing areas (p. 3-30).

Barriers are ranked as a very high threat for the Trinity River, upper mainstem Eel River, and Klamath River coho salmon populations. For example, dams completely block access to more than 15% of potential coho salmon habitat in the following populations: Upper Rogue River (16%), Shasta River (18%), Upper Klamath River (43%), Upper Trinity

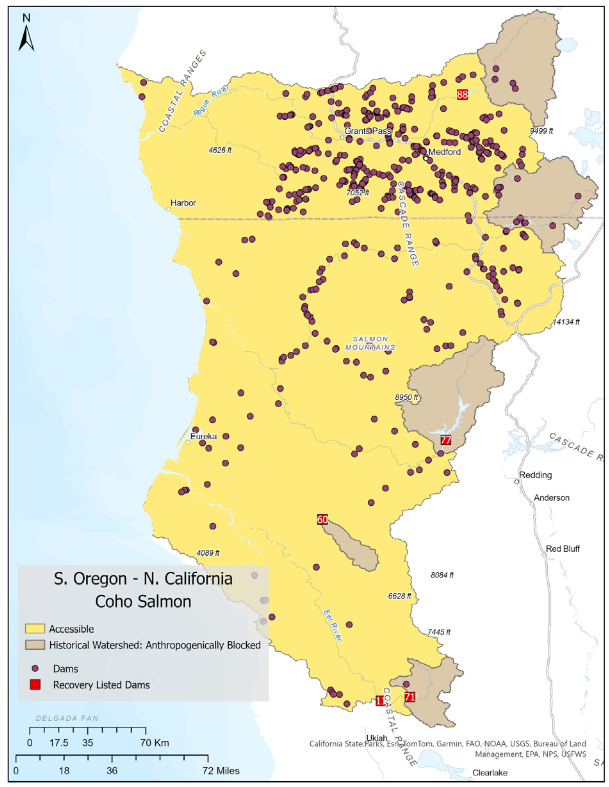

Figure 12. Map of the Southern Oregon/Northern California Coastal coho salmon ESU.

River (47%), and Upper Mainstem Eel River (80%, p. 3-68; Asarian 2014).

The recent removal of dams on the Klamath River will be a significant achievement, opening 644 km (400 mi) of freshwater habitat for this ESU. Furthermore, PG&E has agreed to decommission their facilities at the Potter Valley Project on the Eel River, which will greatly increase availability of coolwater habitat for this population. Estimates vary, but removal of these barriers will increase available habitat by 169–467 km (105–290 mi; FitzGerald et al. 2020).

The recovery plan indicated that the most common types of barriers include road–stream crossings (e.g., culverts), dams, tide gates, and agricultural diversions (pp. 7-1–45-14). Unscreened diversions in particular were mentioned at the time of listing as a threat to SONCC coho salmon and are still a concern today (p. 3-29; CDFG 2004a).

Other threats included impairment of habitat quality. Summer and winter rearing habitat is overall impaired because of reduced LWD, habitat complexity, high sediment loads, low flows, lack of winter refugia, and high water temperature. For example, summer water temperatures in Elk, Bald Mountain, Panther, and Butler Creeks do not meet Oregon Department of Environmental Quality (ODEQ) standards (p. 7-10). Elevated summer water temperatures in the South Fork Pistol River are too warm for coho (p. 12-11).

Another major threat to this ESU is marijuana cultivation, typically located near headwater streams. These farms divert cool stream water during the critical summer months; each marijuana plant may consume 900 gallons of water per growing season (p. 3-26). Marijuana operations also build unpermitted roads, thereby impacting coolwater habitat via increased sedimentation and change in flow regime, among other things (p. 3-46). In addition, marijuana cultivation typically uses a variety of herbicides, pesticides, and fertilizers to support these plants, chemicals that are likely impairing water quality in coho salmon streams (p. 3-49).

3.2.3 Oregon Coast recovery domain

Oregon Coast

Status: Threatened

Artificial barriers limiting factor: Low

Adaptive capacity: Moderate

Population viability sensitivity: Moderate

Hatchery influences: NM

Sensitivity to extrinsic factors: Moderate

Overall vulnerability: Moderate

Comments: Dams/barriers were not considered a key threat to recovery (Figure 13).

State and federal reports and findings identify reduced stream complexity and degraded water quality—especially water temperature—as the primary limiting factors for this ESU (p. 3-2).

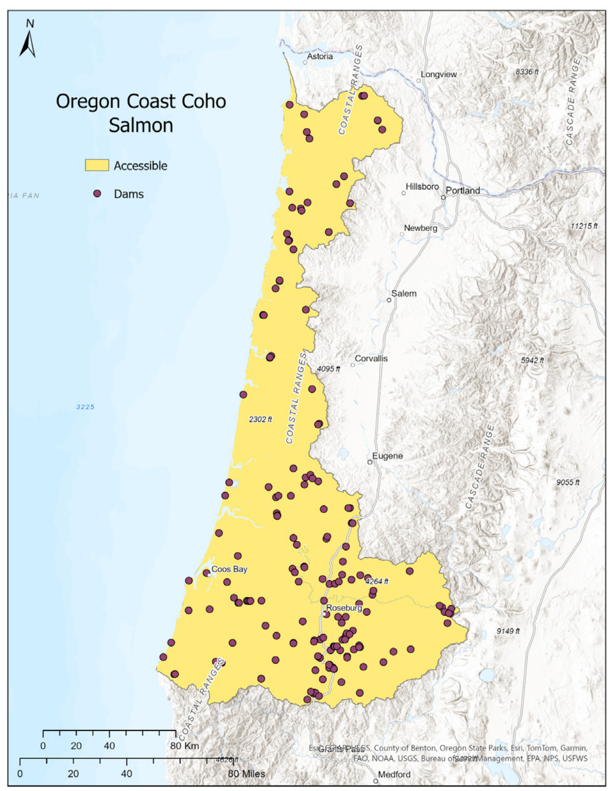

Figure 13. Map of the Oregon Coast coho salmon ESU.

This ESU is particularly limited by a lack of complex winter rearing habitat to provide shelter during high flow events (p. 2-4).

Reduced stream flows is also a factor limiting recovery in portions of the ESU due to human activities, like the Umpqua River system (p. 6-48).

3.2.4 Willamette/Lower Columbia River recovery domain

Lower Columbia River

Status: Threatened

Artificial barriers limiting factor: Low

Adaptive capacity: Moderate

Population viability sensitivity: Moderate

Hatchery influences: Moderate

Sensitivity to extrinsic factors: Moderate

Overall vulnerability: High

Comments: Dams/barriers were not considered a key threat to recovery (Figure 14).

However, this ESU is affected by a variety of other threats, including warmer water temperatures, altered flow regimes, and loss and modification of habitat, especially in the Lower Columbia River and estuary (pp. 3-8–3-9).

In addition, dams and reservoirs within this ESU have led to major changes in critical habitat due to changes in thermal, flow, sediment, and organic matter regimes (p. 4-10).

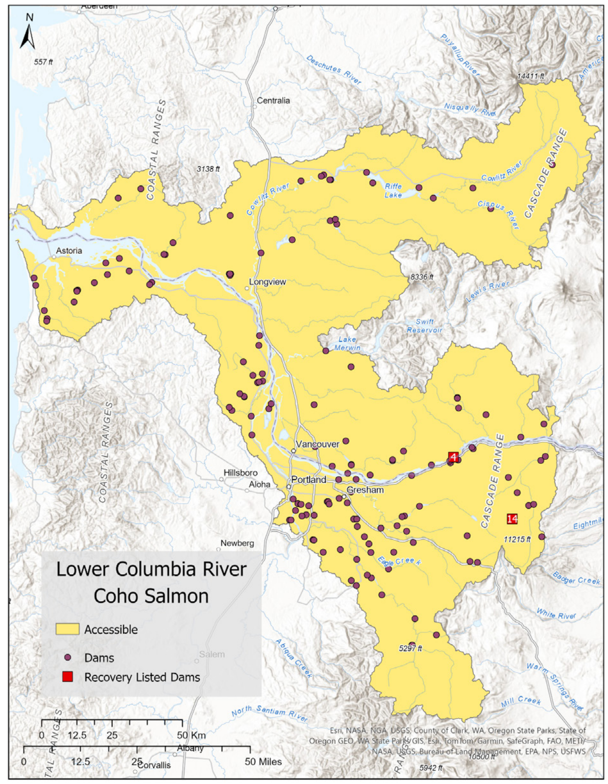

Figure 14. Map of the Lower Columbia River coho salmon ESU.

Contaminants in the estuary may also be limiting to this ESU (p. 4-11).

3.3 Chum Salmon (*Oncorhynchus keta*)

3.3.1 Willamette/Lower Columbia River recovery domain

Columbia River

Status: Threatened

Artificial barriers limiting factor: Low

Adaptive capacity: Moderate

Population viability sensitivity: Moderate

Hatchery influences: Low

Sensitivity to extrinsic factors: Low

Overall vulnerability: Moderate

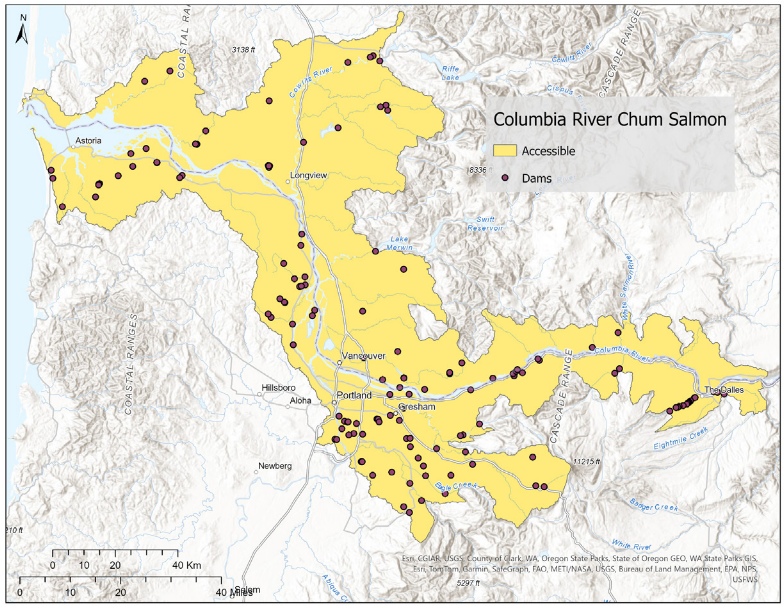

Figure 15. Map of the Columbia River chum salmon ESU.

Comments: Dams/barriers were not considered a key limiting factor (Figure 15).

However, this ESU is affected by a variety of other threats, including warmer water temperatures, altered flow regimes, and loss and modification of habitat, especially in the Lower Columbia River and estuary (pp. 3-8–3-9). In addition, dams and reservoirs within this ESU have led to major changes in critical habitat due to changes in thermal, flow, sediment, and organic matter regimes (p. 4-10).

3.3.2 Puget Sound recovery domain

Hood Canal summer-run

Status: Threatened

Artificial barriers limiting factor: Low

Adaptive capacity: Moderate

Population viability sensitivity: High

Hatchery influences: Low

Sensitivity to extrinsic factors: Low

Overall vulnerability: Moderate

Comments: Dams/barriers were not considered a key limiting factor (Figure 16). Overall, altered sediment transport and habitat complexity are major problems in this ESU. For example, in Salmon and Snow Creeks, habitat complexity and sediment loads are identified as the primary limiting factors (p. 86). The Hamma Hamma and Duckabush–Dosewallips Rivers suffer from reduced habitat complexity, channel stability, and sediment loads (p. 102).

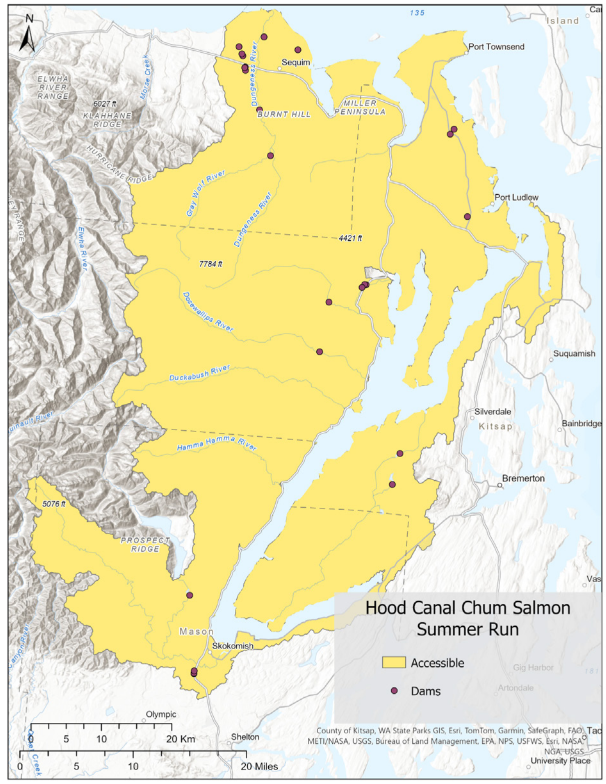

Figure 16. Map of the Hood Canal chum salmon summer run.

3.4 Sockeye Salmon (*Oncorhynchus nerka*)

3.4.1 Interior Columbia recovery domain

Snake River

Status: Endangered

Artificial barriers limiting factor: Very high

Adaptive capacity: Low

Population viability sensitivity: Very high

Hatchery influences: Low

Sensitivity to extrinsic factors: High

Overall vulnerability: Very high

Comments: As observed in many Columbia River ESA listings, the viability of Snake River sockeye salmon is strongly affected by their navigating eight Columbia River mainstem dams (Figure 17). The recovery document also states artificial barriers, including culverts and small dams, remain around natal lakes (p. 152).

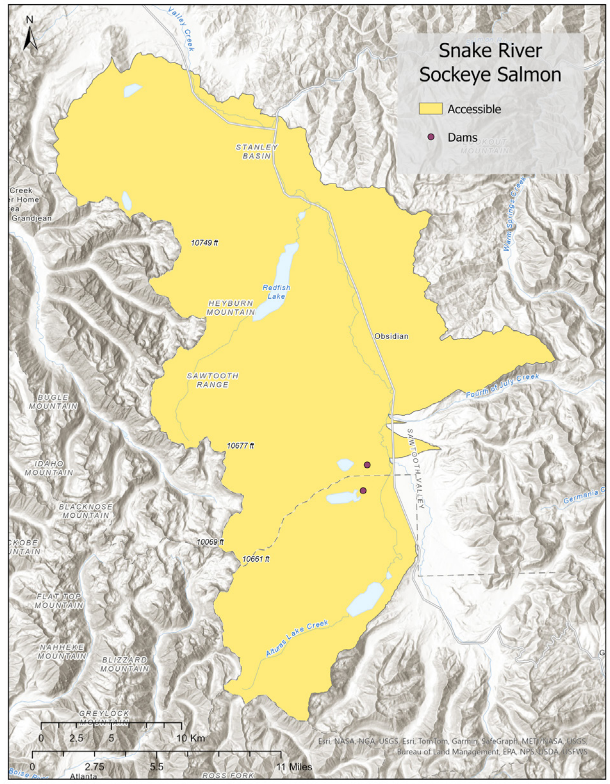

Figure 17. Map of the Snake River sockeye salmon ESU.

A majority of the land base for this ESU consists of federally managed forests and grasslands or wilderness areas. However, portions of the ESU that are not on protected lands are degraded by loss and simplification of stream, riparian, and floodplain habitats resulting from current and past land use activities, such as logging, grazing, agriculture, and mining. Table 5-1 and Figure 5-2 in the recovery plan describe limiting factors in tributary habitats and populations affected by each factor (pp. 169–170), while Section 5.1.2.4 discusses threats and potential impacts of limiting factors associated with each threat (pp. 170–171).

3.4.2 Puget Sound recovery domain

Ozette Lake

Status: Threatened

Artificial barriers limiting factor: Low

Adaptive capacity: Low

Population viability sensitivity: High

Hatchery influences: Moderate

Sensitivity to extrinsic factors: High

Overall vulnerability: Moderate

Comments: Dams/barriers were not considered a key limiting factor (Figure 18).

Based on the 2022 status review, concerns at the time of listing that remain valid at this time include vegetation encroachment on sockeye spawning beaches, high water temperatures in Ozette Lake and Ozette River, and low water flows that create thermal blocks to migration (p. 50).

Based on the loss of beach spawners, there appears to be an increase in biological risk for Ozette Lake sockeye (p. 14).

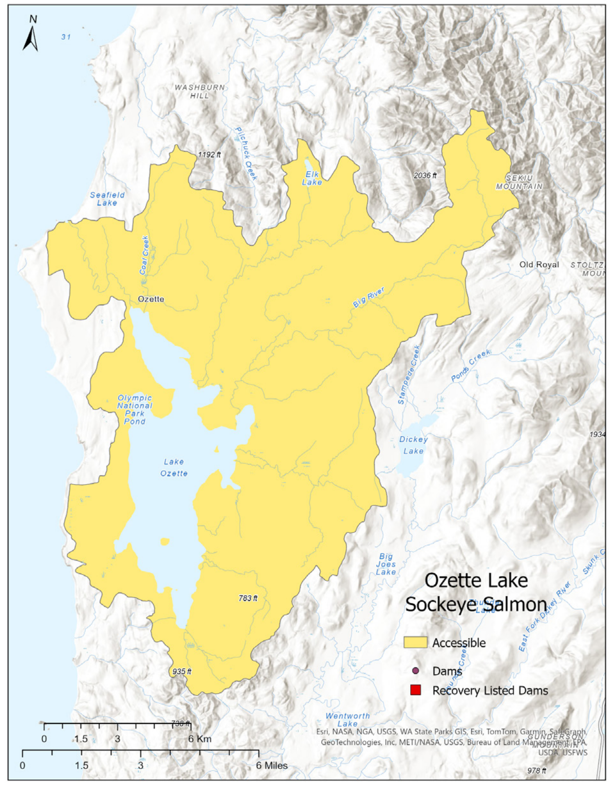

Figure 18. Map of the Ozette Lake sockeye salmon ESU.

3.5 Steelhead Trout (*Oncorhynchus mykiss*)

3.5.1 South Central/Southern California recovery domain

Southern California Coast

Status: Endangered

Artificial barriers limiting factor: Very high

Adaptive capacity: Low

Population viability sensitivity: High

Hatchery influences: Low

Sensitivity to extrinsic factors: High

Overall vulnerability: Very high

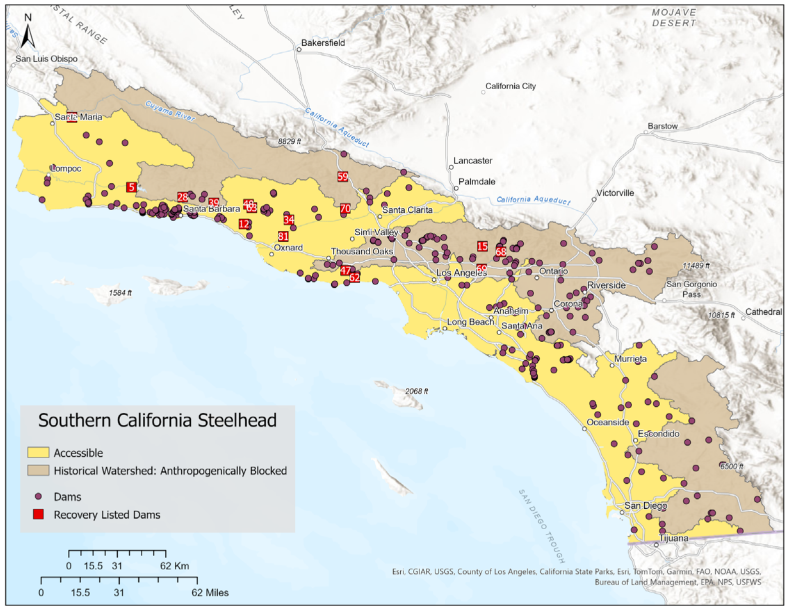

Figure 19. Map of the Southern California Coast steelhead trout DPS.

Comments: Recovery of this DPS (Figure 19) depends on access to historic habitat above artificial barriers (pp. 7-7–7-8, 7-16, their Figure 7-1). Dams block access to about 70% of historic habitat (p. 9-11).

This recovery plan lacked details on links between other limiting factors and the recovery of this DPS. However, it did describe how the coastal terraces and floodplains of watersheds within the DPS are subjected to more intensive land use than interior portions (p. 9-4). Many of the coastal portions of watersheds within this DPS are impacted by urbanization (e.g., near population centers—Santa Paula, Fillmore), while the upper portions are within U.S. National Forests (p. 9-4). Habitat alteration caused by urbanization includes changes in hydrology, sedimentation, thermal regimes, floodplain connectivity, and habitat simplification and loss.

South Central California Coast

Status: Threatened

Artificial barriers limiting factor: Very high

Adaptive capacity: Moderate

Population viability sensitivity: Moderate

Hatchery influences: Low

Sensitivity to extrinsic factors: High

Overall vulnerability: Very high

Comments: Recovery of this DPS (Figure 20) depends on access to historic habitat above artificial barriers (pp. 4-1, 7-15–7-19, 7-24, their Figure 7-1) . In the 2023 five-year review, dams are mentioned as ongoing habitat concerns, including dams without passage (e.g., p. 73) such as San Antonio, Nacimiento, and Santa Margarita Dams affecting the Interior Coast Range biological population group (BPG). In addition, Pickell Dam can pass fish but still impedes volitional fish passage (p. 50). The 2023 update also mentions dams as impediments to fish passage affecting the Carmel Creek (p. 59) and San Luis Obispo Terrace BPGs, including Marre Dam (p. 69). The status of fish passage barriers is in flux, with existing ones being removed or modified, while new ones may be installed, or discovered through updated inventories; a current list of priority fish passage impediments can be found on the California Department of Fish and Wildlife website.[8]

According to the recovery plan, other threats limiting the recovery of this DPS include urbanization; agricultural impacts; and modification of hydrology sediment, thermal, and organic matter dynamics by dams (pp. 3-2, 4-5, 8-3, 9-10). For example, agricultural activities within the Interior Coast Range BPG have significantly impacted steelhead habitat through encroachment into riparian areas, increases in fine sediment and pollutants, reduction in habitat complexity, and extensive water extraction (p. 9-10). In addition, this DPS is impacted by non-native species (p. 3-4) and estuarine loss (p. 4-9).

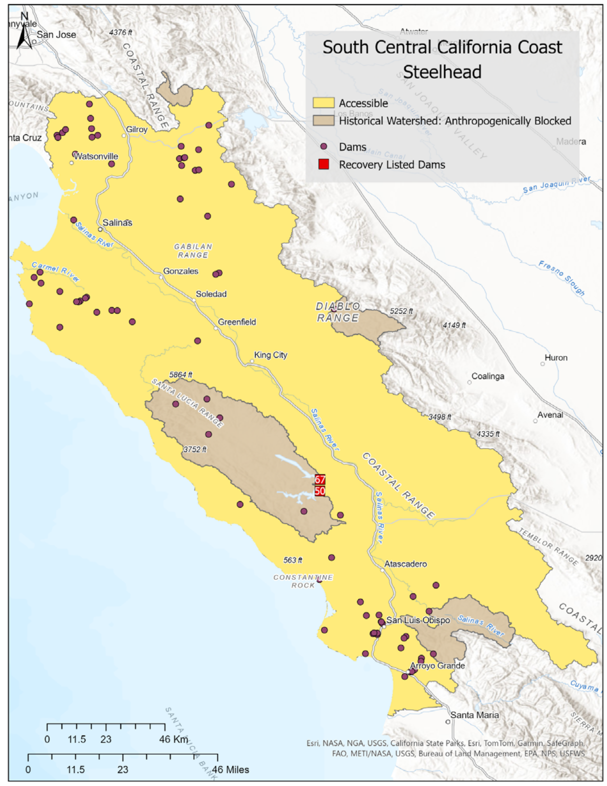

Figure 20. Map of the South Central California Coast steelhead trout DPS.

[8] https://www.cafishpassageforum.org/

3.5.2 Central Valley recovery domain

California Central Valley

Status: Threatened

Artificial barriers limiting factor: Very high

Adaptive capacity: Moderate

Population viability sensitivity: Moderate

Hatchery influences: High

Sensitivity to extrinsic factors: Moderate

Overall vulnerability: Very high

Comments: The recovery plan (pp. 7–8) states that this DPS depends on access to historic habitat above artificial dams/barriers (Figure 21) . Dams block access to 80% of historic habitat and block access to spawning grounds for about 38% of all populations (p. 55). The plan lists passage impediments threatening this DPS (p. 60), including Friant Dam on the San Joaquin River, La Grange and Don Pedro Dams on the Tuolumne River, Goodwin and New Melones Dams on the Stanislaus River, and Camanche and Pardee Dams blocking access to historic habitat on the Mokelumne River. Dams mentioned in the 2016 five-year status review include Folsom Dam on the American River (p. 39), Shasta Dam on the Sacramento River (p. 39), and New Exchequer Dam on the Merced River (p. 26).

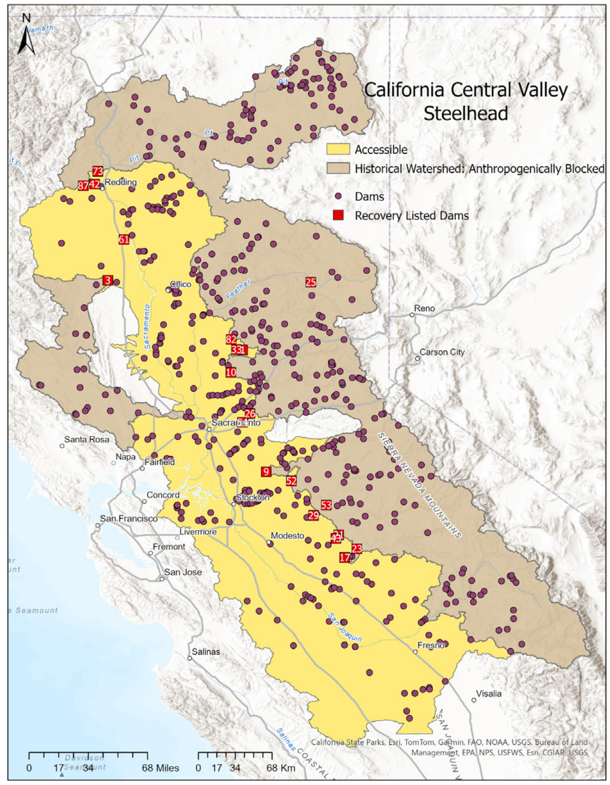

Figure 21. Map of the California Central Valley steelhead trout DPS.

There are multiple other threats to this DPS, including: increased summer temperatures, especially in dry years; altered flow regime; habitat modification and simplification; loss of floodplain habitat; historic mining operations; agricultural and mine runoff; predation by non-native fish; and a highly modified estuary in the Sacramento–San Joaquin Delta (pp. 11, 13, 21, 44–45, and elsewhere).

3.5.3 North-Central California Coast recovery domain

Central California Coast

Status: Threatened

Artificial barriers limiting factor: Very high

Adaptive capacity: High

Population viability sensitivity: Moderate

Hatchery influences: Moderate

Sensitivity to extrinsic factors: Moderate

Overall vulnerability: Very high

Comments: To meet the minimum biological viability criteria, passage above several dams (Figure 22) is recommended for the Central California Coast steelhead recovery scenario (p. 1 and their Appendix G).

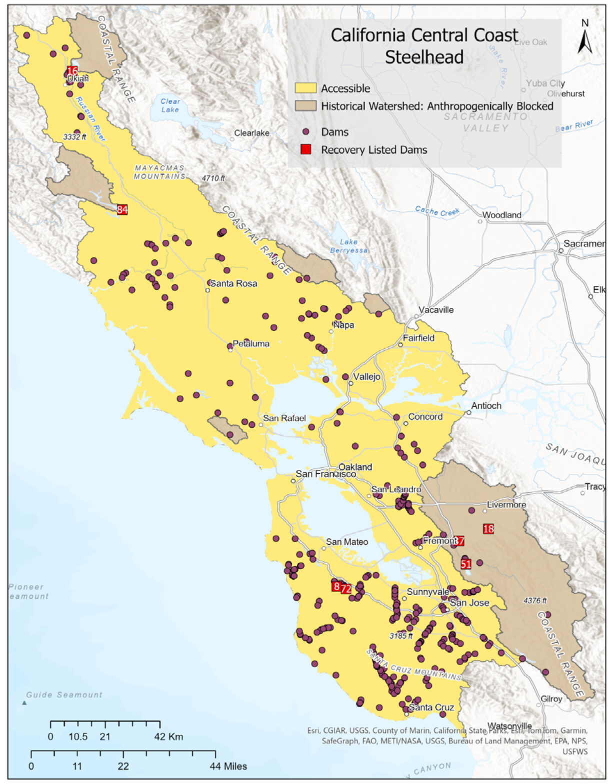

Figure 22. Map of the California Central Coast steelhead trout DPS.

Passage at Searsville Dam will restore access to approximately 14.3 km (8.9 mi) of historic steelhead habitat, and passage at the Upper Diversion Dam will restore access to approximately 3 km (1.9 mi) of high-quality habitat (p. 562).

The extent of anadromy will be limited by the three long-standing dams (Calaveras, Turner, and Del Valle Dams) within the watershed Almeda Creek population (p. 650).

The Napa River watershed is impacted by many in-channel structures, such as bridge aprons, flow diversions, culverts, road crossings, and dams that are complete or partial barriers to juvenile and adult steelhead migration (p. 741).

Several large impoundments impair steelhead migration on the mainstem within the Upper Russian River population, and numerous smaller dams preclude or impair steelhead migration into sections of the watershed (p. 402).

Dams and urban development completely block passage to ~82% of the stream miles in the Guadalupe River watershed, precluding access to historically important spawning and rearing reaches (p. 495).

According to the recovery plan, this DPS faces a number of challenges other than barriers. Many large rivers and streams suffer from high summer water temperatures, increased sedimentation, altered flows including low flows in summer, and habitat loss and simplification. In addition, many estuarine habitats are degraded, including high summer temperatures (pp. 467, 470, 497).

Northern California summer run

Status: Threatened

Artificial barriers limiting factor: Very high

Adaptive capacity: High

Population viability sensitivity: Moderate

Hatchery influences: Moderate

Sensitivity to extrinsic factors: Moderate

Overall vulnerability: High

Comments: The recovery plan states that the Cape Horn and Scott Dams inflicted significant anthropogenic changes on the upper mainstem Eel River population (pp. 98, 459–460). Scott Dam blocks about 99% of the habitat for the upper mainstem Eel River summer steelhead population (Figure 23).

PG&E announced in 2023 that they will remove Cape Horn and Scott Dams.

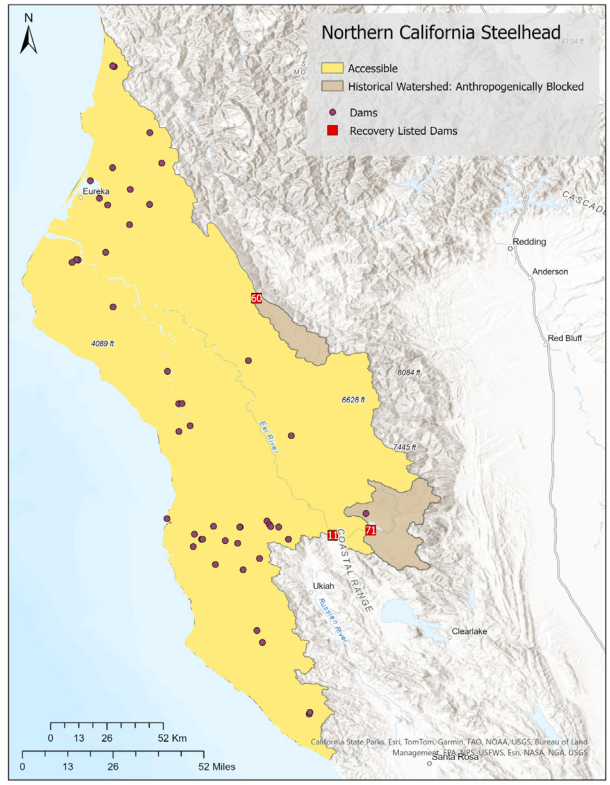

Figure 23. Map of the Northern California steelhead trout DPS.

Many large rivers and streams in this DPS are listed as impaired by the EPA and the state Water Quality Control Board for temperature and sediment pollution (p. 16). Many of these listed water bodies, however, will be developing total maximum daily load plans (TMDLs) to address these impairments. Also, streams in this DPS generally exhibit reduced habitat complexity and altered stream flows (p. 7). In fact, all diversity strata within this DPS are limited by stream habitat complexity (p. 33).

A more recently recognized threat, illicit agriculture (specifically, illicit marijuana cultivation, a growing new threat within the DPS), falls within the previously recognized threat category of agriculture in general, but is distinguished by being an illegal unregulated activity that does not benefit from the resource management oversight afforded by regulated agricultural operations. Unregulated pesticides use, habitat destruction, and illegal damming and diversion of rural streams and rivers for the purpose of irrigating illegal marijuana growing operations is likely now the paramount threat to salmonid survival and habitat function in many first- and second-order streams located in remote, rural areas (p. 5).

3.5.4 Willamette/Lower Columbia recovery domain

Lower Columbia River

Status: Threatened

Artificial barriers limiting factor: Very high

Adaptive capacity: High

Population viability sensitivity: Moderate

Hatchery influences: High

Sensitivity to extrinsic factors: Moderate

Overall vulnerability: High

Comments: In addition to the effect of dams on the mainstem Columbia River, the recovery plan for this DPS reports that the effects of tributary dams vary among steelhead subpopulations (Figure 24). Construction of tributary and mainstem dams has constrained the spatial structure of some steelhead populations by blocking or impairing access to historical spawning areas. Dams are listed as a primary or secondary threat to recovery for many populations (e.g., pp. 9-18, 9-21).

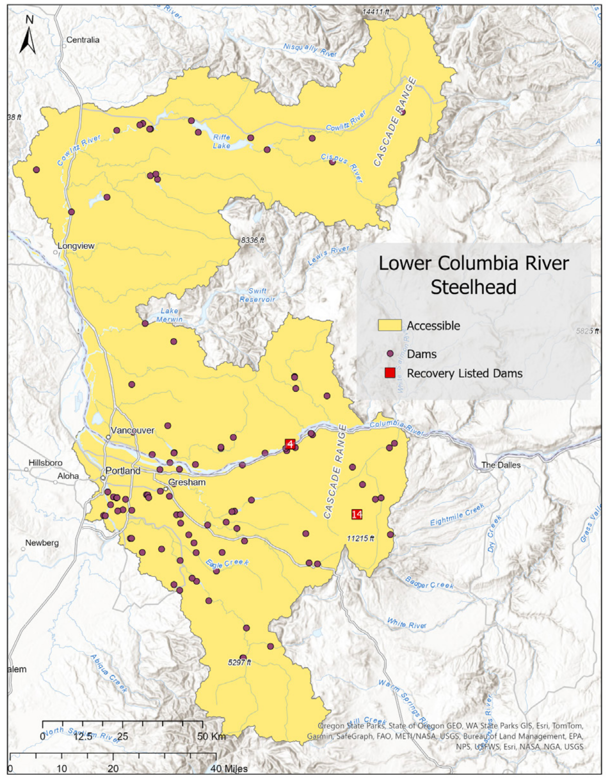

Figure 24. Map of the Lower Columbia River steelhead trout DPS.

In the Cascade winter steelhead stratum, hydropower development is a primary limiting factor for adults and juveniles in the Upper Cowlitz, Cispus, and North Fork Lewis River populations—historically among the most productive winter steelhead populations. In 2007, the Marmot and Little Sandy Dams, which blocked 169 km (105 mi) of riverine habitat, were removed, allowing for re-establishment of steelhead populations above the dam.[9] For the Tilton River population, access to significant amounts of historical habitat has been blocked by tributary dams. Steelhead distribution has been partially restored in the Upper Cowlitz, Cispus, and Tilton Rivers sub-basin by trapping and transferring adults and juveniles around impassable dams (p. 9-7). There are no tributary hydropower facilities in the Coweeman, Toutle, Kalama, Salmon Creek, or Washougal sub-basins (p. 9-25).

While blocking historic habitat, these dams—along with mainstem dams—also cause adverse impacts on downstream habitat, including reduced gravel recruitment and habitat complexity, changes in stream flow including reduced water availability, and altered temperature regimes and food webs (pp. 9-22, 9-25). For example, the large reservoirs associated with mainstem dams contribute to elevated water temperatures downstream in late summer and fall (p. 9-24).

[9] ODFW story on the removal of Marmot Dam: https://www.dfw.state.or.us/news/2017/10_Oct/101917b.asp

Riverine habitat for this DPS is affected by a variety of other environmental threats, including warmer water temperatures, altered flow regimes, and loss and modification of habitat, especially in the Lower Columbia River (pp. 4-2–4-5).

Contaminants, elevated temperatures, habitat degradation, and altered food web dynamics were identified as secondary limiting factors for this DPS in the estuary (pp. 4-10–4-12, 9-24).

Upper Willamette River

Status: Threatened

Artificial barriers limiting factor: Very high

Adaptive capacity: Moderate

Population viability sensitivity: NM

Hatchery influences: High

Sensitivity to extrinsic factors: High

Overall vulnerability: Very high

Comments: The Willamette Project Biological Opinion (NMFS 2008) noted that the Willamette Project adversely affects Upper Willamette River steelhead by blocking access to a large amount of their historical habitat upstream of the dams (Figure 25) and by contributing to degradation of downstream habitat (p. 1-10), including reduced recruitment of spawning gravel and wood (p. 5-48). Detroit and Big Cliff Dams on the North Santiam River are complete barriers to upstream adult migration, blocking access to an estimated 55–65% of the historical production area for steelhead alone (p. 5-48). Other major concerns for this DPS include adverse thermal and flow regimes downstream from the dams (e.g., pp. 3-6, 5-50).

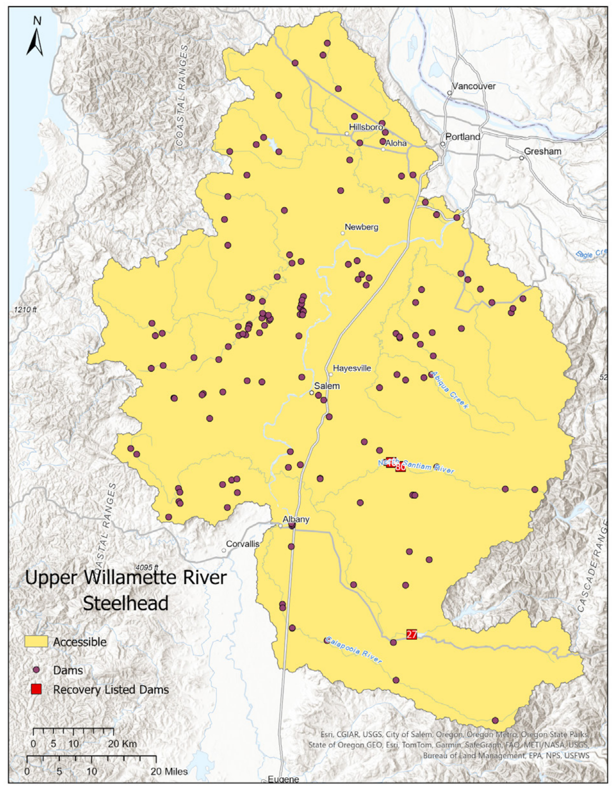

Figure 25. Map of the Upper Willamette River steelhead trout DPS.

The plan emphasizes the importance of successful reintroduction of reproducing steelhead above flood control dams in the Willamette sub-basins, and of downstream passage of offspring (p. 1-8).

3.5.5 Interior Columbia recovery domain

Middle Columbia River

Status: Threatened

Artificial barriers limiting factor: Very high

Adaptive capacity: Moderate

Population viability sensitivity: NM

Hatchery influences: High

Sensitivity to extrinsic factors: High

Overall vulnerability: High

Comment: In addition to migrating through multiple mainstem Columbia River dams, these populations must navigate hundreds of small dams, diversions, and culverts. Impaired fish passage is identified as a primary or secondary limiting factor for all populations of Middle Columbia steelhead (Figure 26). Dams, culverts, seasonal pushup dams, and unscreened diversions can directly prevent migration; seasonal areas of high water temperature, low flow, or dewatering can also function as barriers. There are various kinds of anthropogenic barriers in tributaries throughout the basin, and all populations of Middle Columbia River steelhead use the mainstem Columbia River to migrate to and from the ocean. For example, fish passage at Cle Elum, Kachess, and Keechelus Dams would make an important contribution to achieving recovery goals (p. 3-18). The report notes that passage obstructions (e.g., dams and culverts) should be removed or modified to improve survival and restore access to historically accessible habitat where necessary to support recovery goals (p. 3-19). The Pelton–Round Butte Dam Complex on the Deschutes River blocks volitional fish passage to upstream habitat on the Deschutes, Crooked, and Metolius

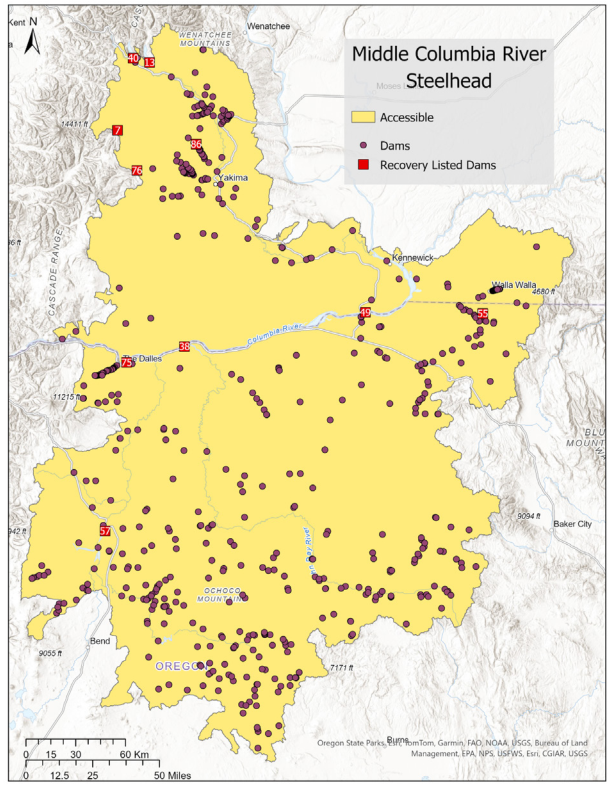

Figure 26. Map of the Middle Columbia River steelhead trout DPS.

Rivers and smaller tributaries (p. 6-9). Although the Pelton–Round Butte Dam Complex uses trap-and-haul of adult and juvenile salmonids, the effectiveness of these actions is questionable.[10]

Several barriers were noted in the 2022 five-year status review. These include the Tieton, Wenas, Cle Elum, Keechelus, Kachess, and Bumping Dams affecting the Yakima River population (p. 26) and Bennington, Nursery Bridge, and McKay Dams affecting the Walla Walla and Umatilla River populations (p. 28). Also mentioned in the 2022 status review was the removal of the Bateman Island Causeway that affects Yakima River populations (p. 27).

[10] https://nativefishsociety.org/news-media/how-is-fish-reintroduction-on-the-deschutes-going

For the recovery of this DPS, the report notes passage obstructions (e.g., dams and culverts) must be removed or improved to improve survival and restore access to historically accessible habitat where necessary to support recovery goals (p. 3-19).

Snake River

Status: Threatened

Artificial barriers limiting factor: Very high

Adaptive capacity: Moderate

Population viability sensitivity: High

Hatchery influences: High

Sensitivity to extrinsic factors: High

Overall vulnerability: Very high

Comments: The fish have lost access to large blocks of their historical habitat (Figure 27). In 1901, construction of Swan Falls Dam on the Snake River blocked access to mainstem and tributary habitat above RM 457.7. More historical habitats (above RM 247) on the mainstem Snake River were lost after construction of the three-dam Hells Canyon Complex (1955–67). Dam construction also blocked and/or hindered fish access to historical habitat in major tributaries. Steelhead populations in the North Fork Clearwater River sub-basin were eliminated in the early 1970s following construction of Dworshak Dam (p. 26). Many smaller dams—and some temporary dams—were also built on tributaries at this time without fish passage facilities and had the same effects, though on much smaller scales. The loss of this historical habitat significantly reduced the spatial structure that was once available to the species.

The Hells Canyon Complex blocked access to 338 km (210 mi) of historic mainstem

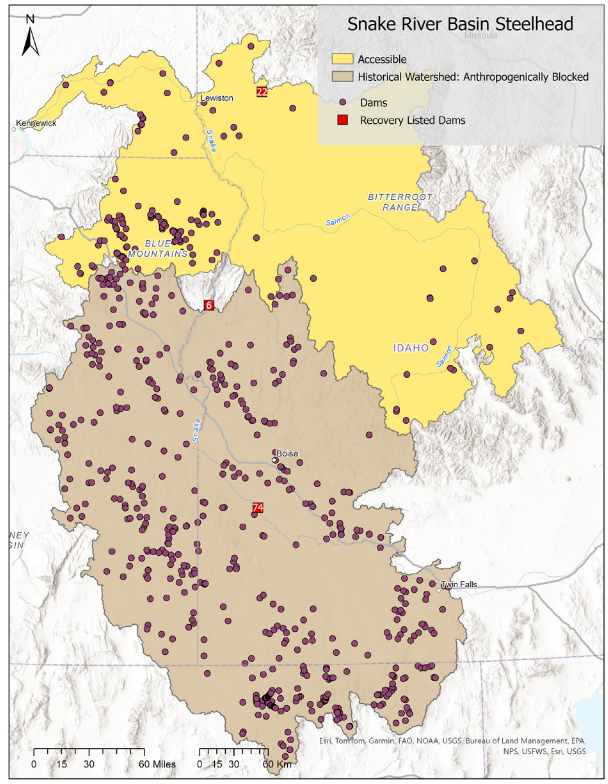

Figure 27. Map of the Snake River steelhead trout DPS.

Snake River habitat, in addition to hundreds of miles of tributary habitat. In all, approximately 4,023 km (2,500 mi) of historical anadromous fish habitat have been lost to barrier dams and inundation (p. 58).

To improve the odds of recovery for the DPS, fish passage obstructions (e.g., dams and culverts) need to be removed or modified to improve survival and restore access to historically accessible habitat where necessary (p. 104).

Upper Columbia River

Status: Threatened

Artificial barriers limiting factor: Very high

Adaptive capacity: Moderate

Population viability sensitivity: High

Hatchery influences: High

Sensitivity to extrinsic factors: High

Overall vulnerability: High

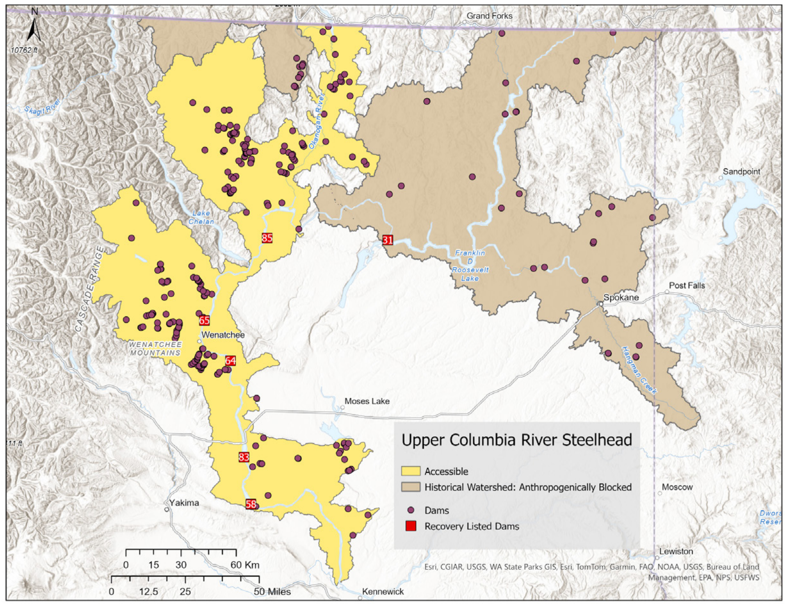

Figure 28. Map of the Upper Columbia River steelhead trout DPS.

Comment: The existence and operation of the Columbia River Hydrosystem presents passage obstacles to both adult and juvenile migrants (Figure 28). Populations of spring Chinook salmon and steelhead in the Okanogan and Methow River sub-basins must pass through nine dams; populations in the Entiat River sub-basin must pass through eight dams; and those in the Wenatchee River sub-basin pass through seven dams (p. 11).

Grand Coulee and Chief Joseph Dams eliminated access to the Columbia River upstream of those projects. Several hundreds of suitable rearing and spawning habitats are located above these dams.[11] The Bonneville Power Administration recently entered an agreement with several tribal nations to reintroduce sockeye, steelhead, and Chinook salmon above these dams.

Other threats to this DPS include the effects of dam operations on river and riparian habitat, including: altered flow, thermal, organic matter, nutrient, and sediment regimes; loss of habitat structure, complexity, and floodplain connectivity; loss and contamination of estuarine habitat; contamination of mainstem habitat near urban centers (p. 5-10); and predation by non-natives (p. 5-9).

[11] https://ucut.org/wp-content/uploads/2022/08/UCUT-Phase-2-Implementation-Plan-Version-4Aug2022.pdf

3.5.6 Puget Sound recovery domain

Puget Sound

Status: Threatened

Artificial barriers limiting factor: Moderate–high

Adaptive capacity: Moderate

Population viability sensitivity: Moderate

Hatchery influences: High

Sensitivity to extrinsic factors: High

Overall vulnerability: High

Comments: Large dams in some watersheds have reduced the abundance of steelhead populations and limited their distribution within and among watersheds (Figure 29). In addition to eliminating access to habitat, dams affect habitat quality through changes in river hydrology, temperature profile, downstream gravel recruitment, and the movement of large wood (p. 16). The recovery plan describes a number of strategies to address the effects of dams, including removing high-priority dams that block or impair steelhead migration into historical habitat (p. 18).

Fish passage projects at major dams and blockages, such as Baker River (Skagit River) and the Hiram Chittenden Locks (Cedar River–Lake Washington Watershed), provide the greatest and timeliest opportunity to increase VSP criteria for steelhead in Puget Sound. Fish passage around major structural features like dams can take a decade or more to plan and implement, but measurable increases in steelhead abundance to newly available, high-quality habitat can occur within several generations (12–20 years).

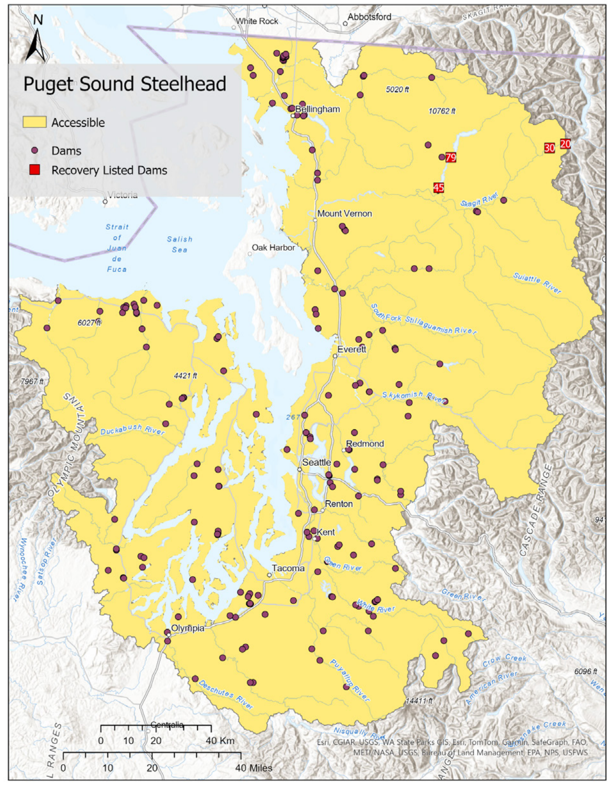

Figure 29. Map of the Puget Sound steelhead trout DPS.

Several dams in the Skagit River system block upstream passage for steelhead, and the city of Seattle recently entered an agreement with local tribal nations to explore reintroducing these fish above the barriers, providing salmon with access to potentially 113–169 km (70–100 mi) of high-quality habitat.[12] Dams on the Baker River, a large Skagit River tributary, blocks access to significant but unreported amounts of relatively high-quality habitat.

Dams also influence riverine habitat for this DPS. The Puyallup and White River populations are affected by altered sediment and flow transport because of dams (p. 282).

[12] https://www.kuow.org/stories/getting-fish-passage-over-skagit-dams-will-be-a-decades-long-process

This DPS is impacted by a number of other threats. Habitat loss and degradation is particularly severe in and around urban centers, including several EPA superfund sites and migratory bottlenecks (e.g., the Ballard Locks). For example, water temperatures reach thresholds that affect Chinook salmon mortality along portions of the Nooksack River (SSDC 2007, p. 70). Since steelhead trout respond similarly to temperature, these temperature thresholds on the Nooksack River may also affect steelhead mortality.

Although some efforts have been made to clean up industrial contaminants, they remain a major threat to this DPS, especially near urban centers like Seattle and Tacoma (p. 72).

4. Phase II—Proposed Methodology

For several reasons, we suggest that the best approach to Phase II—the data verification phase—is to use a web-based application (app). The app is designed for ease of use and data collection, storage, analysis, and presentation, ultimately supporting and augmenting findings from Phase I. It allows us flexibility in receiving and processing data from a diverse expert group both within and outside NOAA, including other agencies, tribal nations, nonprofits, and academia. Gathering diverse perspectives and experiences allows for a more comprehensive understanding of the dams or other artificial barriers which should be considered for circumvention in order to increase the resilience of anadromous salmonid populations to climate change along the U.S. West Coast. The more perspectives we can bring to bear on this complex issue, the better the solutions we can propose.

The app allows a local expert to provide first-hand information on how dams and other environmental stressors impact a particular ESU/DPS (e.g., Snake River steelhead) that was not detected in our review, and to confirm, clarify, and correct Phase I findings. The app also provides an opportunity for experts to name barriers that were overlooked in recovery documents.

Below, we provide additional information on the web-based app—already developed and tested by several NMFS biologists—we propose using to accomplish Phase II. We decided the app was the most effective approach for data verification for the following reasons:

1. **Efficiency:** With the app, we can easily reach experts and record, track, summarize, and visualize responses, both of the individual and of the entire expert community. The app has been beta tested and is relatively user-friendly, allowing for efficiency in data entry and visualization.
2. **Information quantity and quality:** After reviewing all the recovery plans and five-year status reviews, we found a range of information quantity and quality with respect to dams/barriers as a factor limiting the ESU. For example, the plans dealing with recovery of Chinook salmon and steelhead in the Central Valley domain provide sufficient detail on problematic barriers limiting populations, while other plans (e.g., Puget Sound Chinook salmon) were not as detailed, likely due to the approach used in creating the plan and the suite of key limiting constraints. More detailed information might be found in project reports by local watershed groups, but locating and reviewing these reports was beyond the scope of our project. We anticipate that local expert input will inform us not only of problematic dams/barriers not mentioned in reviewed documents, but also of the type and severity of other environmental stressors.
3. **Sample size:** A web-based app also allows us to efficiently reach a diverse and large number of individuals, greatly increasing our potential sample population size and diversity of knowledge and expertise. A larger and more diverse sample population is critical for many reasons, including increasing the accuracy of average values for each problematic dam and helping identify outliers.
4. **Data analysis:** The app allows us to easily summarize scores within the app and interface with statistical programs, such as R, to facilitate more rigorous data analysis and graphical presentation.

5. Phase II—Results

As mentioned previously, to facilitate the collection of information from local experts, the NWFSC data management team developed an app, which we thought would be a more effective and efficient tool than sending an email or calling.

Based on comments from beta testers and our own experience with the app, it takes approximately 10–15 minutes for an individual to add data for a specific ESU. We created a notes section where experts can add important dams/barriers to the database for that ESU absent from our analysis, in addition to commenting on other environmental stressors constraining recovery.

The West Coast Dam Verification app instructions (P. Kiffney, unpublished), which are in review and will be available at a later date, describe how to use and navigate the app and provide a set of screenshots from the current build.

6. Next Steps

As discussed previously, our next steps include: 1) exploring adult salmonid intrinsic potential (IP) above each identified barrier as per feedback from NMFS recovery documents and expert input, while also accounting for other existing population limitations, such as current and future water temperature regimes, and 2) developing a list of dams—based on habitat capacity analysis and expert input, considering a variety of factors (e.g., the number of populations affected by dams, the percent increase in available suitable habitat with barrier circumvention)—that have the potential to increase salmon population resilience for each ESA-listed ESU/DPS across the U.S. West Coast.

We have begun efforts to model estimated adult salmonid habitat capacity. This includes reviewing the relevant literature to identify key environmental thresholds that can limit habitat expansion, such as stream channel gradient, and thus be incorporated into models.

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