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Biological Status of Oregon Coast and Southern Oregon/Northern California Coastal Chinook Salmon: Report of the Status Review Team

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Biological Status of Oregon Coast and Southern Oregon/Northern California Coastal Chinook Salmon: Report of the Status Review Team

OC and SONCC Status Review Team

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Background

Chinook salmon are the largest of the Pacific salmon species. Like all Pacific salmon, adult Chinook salmon spawn in rivers, where their young rear for several months before migrating to the sea. After 2–3 years of living and growing in the ocean, the grown fish return to their home rivers to spawn and then die. Populations of Chinook salmon return to spawn in many rivers along the U.S. West Coast, from California to Alaska. Nine Evolutionarily Significant Units (ESUs) of Chinook salmon are currently protected under the Endangered Species Act (ESA). An ESU is a group of Pacific salmon populations that is distinct from other groups in important ways. ESUs also meet the definition of a "species" under the ESA, and are the units NMFS considers for listing as threatened or endangered. Fish in the protected ESUs are threatened by many things, such as habitat destruction, being eaten by marine mammals or birds, overharvest, problems with hatcheries, and climate change.

The Chinook salmon that spawn in rivers on the Oregon and northern California coasts are not currently protected by the ESA. These Chinook salmon belong to two ESUs: the Oregon Coast (OC) ESU, and the Southern Oregon/Northern California Coastal (SONCC) ESU. Both ESUs contain many populations that spawn in different rivers along the coast. Most of these fish return to spawn in the fall, and a smaller number return to spawn in the spring. In the late 1990s, NMFS evaluated the status of these ESUs and concluded they were not at risk of extinction—and therefore did not require ESA protection.

In August 2022, NMFS received a petition from the Native Fish Society and others requesting that the agency take another look at the status of the OC and SONCC Chinook salmon ESUs. The petition was especially concerned about the small number of Chinook salmon that return to spawn in the spring. NMFS decided that the petition provided sufficient evidence to indicate that the ESUs might be at risk of extinction, and initiated a status review. This report contains the results of that review. The goals were to:

- Find and analyze the best available information on the status of the OC and SONCC Chinook salmon ESUs.
- Determine if these ESUs were correctly identified in the earlier reviews, and update which rivers belong to each ESU, if needed.
- Evaluate the extinction risk of each ESU, based on things such as how many fish there are and the severity of the threats they face.
- Evaluate how important the Chinook salmon that return in the spring are to the long-term health of each ESU.

The purpose of this report is to synthesize information regarding the status of, and to evaluate the extinction risk of, the species. NMFS will consider the information in this report, along with additional information such as conservation efforts being made to protect the species, and decide whether or not to propose ESA listings for either or both of these ESUs.

Key Takeaways

The report compiled a lot of information on OC and SONCC Chinook salmon and the factors that threaten them. After carefully considering this information, the authors of the report made the following conclusions:

- The best available information does not show any need to change the descriptions of the ESUs.
- The OC Chinook salmon ESU, when considered as a whole, is at low risk of extinction.
- The OC Chinook salmon that return in the spring are at moderate risk, but the review concluded that this risk does not influence the long-term health of the ESU as a whole.
- The SONCC Chinook salmon ESU, considered as a whole, is at low risk of extinction.
- The SONCC Chinook salmon that return in the spring are at moderate risk, and this risk significantly influences the long-term health of the ESU as a whole.
- The SONCC Chinook salmon that spawn in smaller coastal streams are also at moderate risk, and this risk significantly influences the long-term health of the ESU as a whole.
- Both ESUs face a variety of threats. Rising temperatures and ecosystem changes predicted to occur over the next 60 years due to climate change were considered to be the most significant threats.

Links used in this section:

- Chinook salmon: https://www.fisheries.noaa.gov/species/chinook-salmon
- Pacific salmon: https://www.fisheries.noaa.gov/species/pacific-salmon-and-steelhead
- Evolutionarily Significant Units: https://www.fisheries.noaa.gov/laws-and-policies/glossary-endangered-species-act#evolutionarily-significant-unit
- Endangered Species Act: https://www.fisheries.noaa.gov/topic/laws-policies
- Threatened by many things: https://www.fisheries.noaa.gov/species/pacific-salmon-and-steelhead/esa-protected-species
- NMFS evaluated the status of these ESUs: https://repository.library.noaa.gov/view/noaa/3034
- A petition from the Native Fish Society and others: https://media.fisheries.noaa.gov/2022-08/2022%20Chinook%20Petition%20080422_508-compliant.pdf
- NMFS decided: https://www.fisheries.noaa.gov/action/90-day-finding-petitions-list-oregon-coast-chinook-salmon-and-southern-oregon-and-northern
- Climate change: https://www.fisheries.noaa.gov/topic/climate-change

Executive Summary

This report contains a status assessment of two salmon evolutionarily significant units (ESUs): the Oregon Coast (OC) Chinook salmon ESU and the Southern Oregon/Northern California Coast (SONCC) Chinook salmon ESU. The report was prepared by the Status Review Team (SRT) in response to a petition to list these ESUs as threatened or endangered under the Endangered Species Act (ESA), primarily due to threats to the spring-run life-history component of the ESUs.

The goals of the report were to:

1. Evaluate and, if necessary, update the ESU configurations.
2. Conduct a demographic risk analysis for each ESU.
3. Conduct an analysis of threats to each ESU .
4. Evaluate extinction risk of the ESUs, based on information in (2) and (3).
5. Depending on the outcome of (4), evaluate whether either ESU is at moderate or high risk of extinction in a significant portion of its range.

Throughout the report there is a focus on the status of both spring- and fall-run Chinook salmon. Spring (or early) Chinook salmon return to freshwater in the spring and early summer and remain in the rivers several months until they are ready to spawn in the late summer or fall. Fall (or late) Chinook salmon return in late summer or fall and immediately commence spawning. The status of the spring-run life-history was a primary focus of the petition, and these alternative life-history forms are also recognized by state and tribal fishery agencies. All watersheds reviewed in this report support fall runs of Chinook salmon, and many watersheds also support the spring-run life history.

ESU Configuration

The ESA allows listing of species, subspecies, and, for vertebrates, distinct population segments (DPS). The National Marine Fisheries Service (NMFS) uses the concept of an ESU for identifying DPSes of Pacific salmon. An ESU is defined as a population or group of populations that 1) is substantially reproductively isolated from conspecific populations, and 2) represents an important component of the evolutionary legacy of the species.

The current OC and SONCC Chinook salmon ESUs were identified by NMFS in the late 1990s, and include fall- and spring-run Chinook salmon spawning in rivers on the Oregon and northern California coasts. The freshwater range of the OC Chinook salmon ESU includes the rivers on the Oregon coast south of the mouth of the Columbia River down to and including the Elk River. The range of the SONCC Chinook salmon ESU extends from Brush Creek in the north, to the lower portion of the Klamath River at its confluence with the Trinity River (Figure ES-1).

The SRT reviewed the available genetic and ecological information obtained since the original ESU designations. Patterns of genetic variation continue to generally support the originally defined ESU boundaries, although there is some uncertainty about the placement of hatchery and natural spring-run populations in the Umpqua River, and hatchery spring-run populations in the Nestucca and Tillamook rivers. Updated evaluations of adult ocean distribution were also generally consistent with the information originally used to identify the ESUs.

After considering the updated information, the SRT determined that no changes to the current ESU designations were indicated, although the team recommends continuing to study the genetic and ecological relationships of the Umpqua River spring run to the rest of the OC Chinook salmon ESU.

Demographic Risk Analysis

The SRT reviewed the available information on historical and contemporary abundance trends for OC and SONCC salmon, including reviewing historical information on the abundance and distribution of the spring-run life-history pattern. This information is summarized for each ESU below.

OC Chinook salmon ESU

Based on a review of historical documents, we found clear evidence for the occurrence of spring-run Chinook salmon in the Umpqua, Tillamook, Siuslaw, and Nestucca Rivers that predates any known stocking of spring-run Chinook salmon from out-of-basin or out-of-ESU sources. In the case of the Umpqua River, spring-run Chinook salmon were present in numbers sufficient to attract the interest of commercial fisheries. More equivocal evidence also suggests the possible occurrence of early-run Chinook salmon in the Alsea River watershed. For the Siletz River, the information was inadequate for assessing the historical occurrence of early-run Chinook

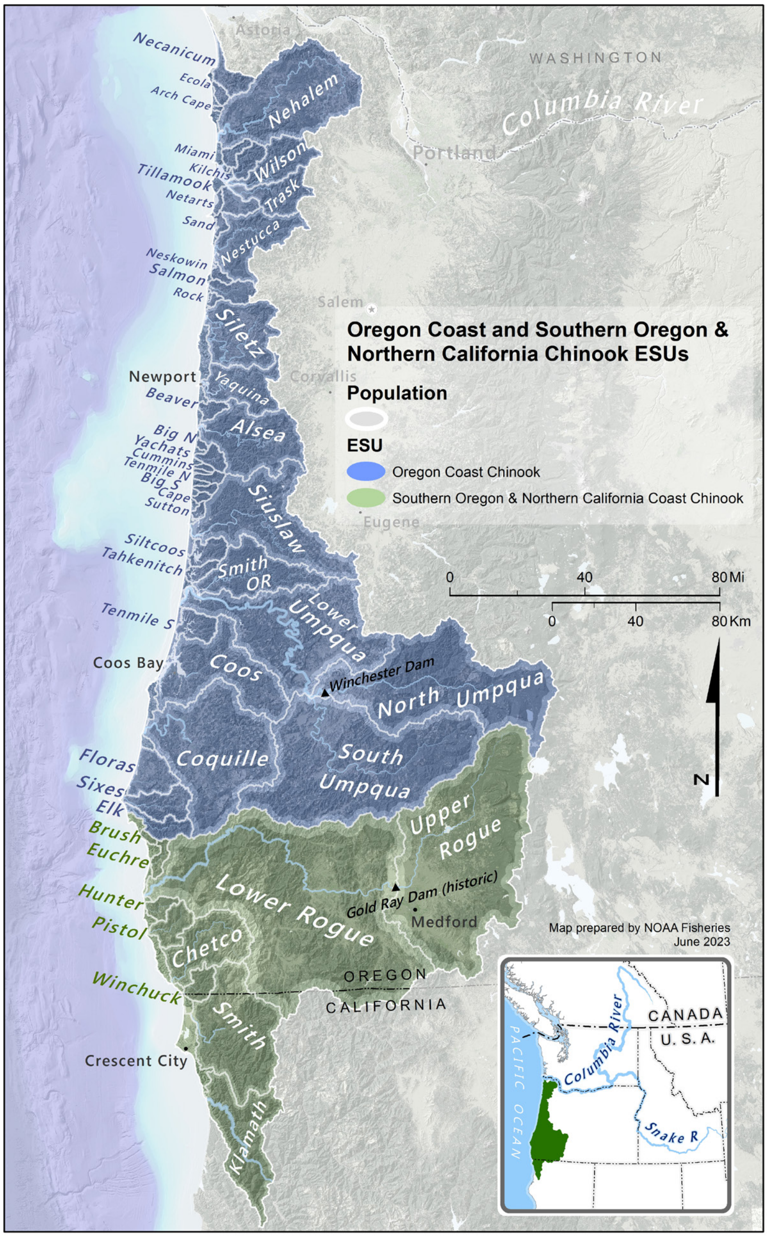

Figure ES-1. Map of OC and SONCC Rivers and ESU boundaries.

salmon, even though there is a contemporary spring run in this system. Though definitive conclusions cannot be reached for other watersheds, the lack of definitive records coupled with the ecological conditions in these watersheds suggests that, if early-run life-history types were present, they were likely substantially lower in abundance than the fall-run component.

Based on a review of published estimates and expansions from cannery records, we concluded that the typical run size in the late 19th century was in the range of 100,000 to nearly 500,000 Chinook salmon returning to Oregon coast rivers.

We conducted an analysis of trends of adult spawning abundance estimates for various Oregon coast rivers, using data from the mid-1980s to 2022. Data were available for all of the major spawning populations in the OC Chinook salmon ESU, consisting of 14 predominantly fall-run and two spring-run populations. Some of the predominantly fall-run populations also contained a spring-run component that the team considered to be demographically part of the fall-run population.

Summed across all populations, the total natural-origin abundance of the fall-run populations was typically between 100,000 and 200,000 spawners, and the spring-run populations combined were typically between 2,500 and 5,000 natural-origin spawners. Trends were variable among populations, with some populations experiencing unusually low recent abundances. Among fall-run populations, about half of the populations have increased over the past 15 years and about half have declined. The two spring-run populations have declined over the past 15 years, but total spring-run abundance remains higher than it was prior to 1960. The spring component of the predominantly fall-run populations is not well monitored, but the available data did not indicate any obvious downward or upward trends.

SONCC Chinook salmon ESU

Evidence from the Rogue River indicates that spring-run Chinook salmon were present in the basin and dominated the commercial catch of Chinook salmon in the early 1890s. Historical records also suggest spring-run Chinook salmon occurred in the Smith River, but accounts of the relative abundance of spring- and fall-run Chinook salmon in that system are conflicting. Commercial catch records from the early part of the 20th century, coupled with the ecological conditions found in the watersheds, would seem to suggest that fall-run was the numerically dominant life-history pattern. Estimates of total late-19th century run sizes for the SONCC Chinook salmon ESU ranged from about 100,000 to 300,000 Chinook salmon.

We conducted an analysis of abundance trends using data obtained from state and tribal fish and wildlife agencies. Spawning abundance data were available for one spring-run and six fall-run populations. Together, these constitute most of the major spawning populations in the SONCC Chinook salmon ESU. Data for the Smith River, an apparently sizable population, were insufficient to evaluate trends. Summed across the ESU (excluding the Smith River), total abundance of fall-run Chinook salmon during the period 1990–2022 typically ranged from 30,000 to >125,000 natural-origin spawners. Several estimates for the Smith River from 2010 to 2021 were between 10,000 and 20,000 fall-run Chinook salmon.

Estimates of spring-run Chinook salmon returning to the upper Rogue River (the only major spring-run population) between 1990 and 2022 ranged from a few thousand to more than 10,000 natural-origin spawners, along with similar numbers of hatchery-origin spawners. Estimates from 1940 to the late 1980s were much higher; typically 30,000 to 50,000 spring-run Chinook salmon. Trends over the past 15 years for the fall-run populations were generally negative, and variable but without an obvious trend for the Rogue River spring-run population.

Summary of threats

The team compiled and evaluated threats related to the "listing factors" in ESA Section 4(a)(1). These include threats from loss or degradation of habitat, over-harvest, disease and predation, inadequate regulatory mechanisms, and other factors, which for these ESUs include the effects of hatcheries and climate change.

There have been numerous prior assessments of OC and SONCC freshwater and estuarine habitat, many done in the context of evaluating habitat needs for ESA-listed OC and SONCC coho salmon. The team reviewed these assessments, taking into account the life-history differences between coho and Chinook salmon. A broad range of historical and ongoing land- and water-management activities and practices have often adversely impacted the freshwater and estuarine habitats used by Chinook salmon, including construction of dams and other barriers, water diversions, channelization and diking, agricultural practices, roads, timber harvest, and urbanization. These activities have altered, or in some cases eliminated, habitat for OC and SONCC Chinook salmon.

The team reviewed data from state, federal, and international fisheries to evaluate trends in harvest of OC and SONCC Chinook salmon. OC Chinook salmon migrate north along the Pacific coast, and are caught in fisheries from California to Alaska. For OC Chinook salmon, total exploitation rates in the ocean and terminal areas combined have typically been ~50% since 1980. Terminal (freshwater or estuarine) harvest rates vary among OC rivers, ranging from 0 to ~40% since 1980.

SONCC Chinook salmon do not migrate as far north, and are mainly encountered in ocean fisheries along the California and Oregon coasts south of Cape Falcon, Oregon. No direct estimates of ocean fishery impacts are made for any stock in the SONCC Chinook salmon ESU, so ocean harvest rates for Klamath River fall-run Chinook salmon are used by managers as a proxy for SONCC stocks. Annual age-4 ocean harvest rates have ranged from 0 to >50% since 1986. Terminal harvest rates vary greatly among populations, typically ranging from close to zero for some rivers and >20% for others. Ocean harvest rates on spring-run SONCC Chinook salmon are believed to be similar to fall-run, and terminal rates have ranged from 0 to >30% since 2004.

The Oregon Department of Fish and Wildlife (ODFW) considers disease to be an important factor that affects the abundance of Chinook salmon in the Rogue River basin. Extensive mortalities of adult Chinook salmon were documented in the mainstem Rogue River in 1977, 1981, 1987, 1992, and 1994, with columnaris the disease most frequently identified in dead and dying fall-run fish. Mortality rates of juvenile Chinook salmon infected with *Flavobacterium columnare* increase as water temperature increases, and summer water temperatures in the Rogue River can approach the range where the disease becomes a significant problem.

Predation by marine mammals and introduced freshwater fishes also influences the abundance of OC and SONCC Chinook salmon. Harbor seals, sea lions, and killer whales (including populations in British Columbia and Alaska that feed on north-migrating salmon) have all increased at least three-fold over the past 50 years, and some studies suggest these increases have resulted in proportional increases in predation pressures on salmon. Smallmouth bass, a non-native freshwater fish species in Pacific coastal lakes and streams, is also a source of concern in some rivers.

Climate change caused by past and ongoing global greenhouse gas emissions is a current threat to Pacific salmon, and is expected to become a larger threat over the next several decades. Globally, the years 2015–20 were the warmest on record, and 2023 is predicted to be among the top five warmest years on record. Rising temperatures and associated ecosystem changes are predicted to impact Pacific salmon by a variety of mechanisms throughout their life cycle.

For the OC and SONCC Chinook salmon ESUs, expected changes to freshwater habitats include increased air and stream temperatures, and changes in seasonal rainfall patterns, with larger and more extreme storms. These increased temperatures will result in more winter precipitation falling as rain than snow at intermediate elevations, which alters both seasonal streamflow and water temperatures. In the OC and SONCC areas, stream temperatures are expected to rise, winter flows to increase, and summer flows to decrease compared to current patterns. For the OC and SONCC Chinook salmon ESUs, the predicted effects of increasing temperatures may be particularly severe for the rivers that are already relatively warm during the summer, such as the Umpqua, Rogue and Coquille Rivers, and less so for others such as northern rivers of the Oregon coast and the Smith River in California. Substantial portions of the spawning and rearing areas in some rivers, including the Umpqua, Rogue, Nehalem, and Coquille Rivers, are predicted to have average August temperatures above 20°C, a point at which salmon are physiologically stressed and subject to greater disease pressures. It is important to note, however, that these predictions are based on average stream temperatures for relatively large river reaches, and do not account for potential small-scale thermal refuges that salmon may use currently and in the future.

The effects of hatchery programs are also a source of potential concern. Hatchery programs can potentially provide demographic benefits to salmon and steelhead, such as increases in abundance during periods of low natural abundance, and they may also help preserve genetic resources until limiting factors can be addressed. However, hatchery programs can also harm naturally produced populations of salmon and steelhead in a variety of ways, including competition and predation effects, disease effects, domestication and other negative genetic effects, and facility effects (e.g., water withdrawals, effluent discharge). High proportions of hatchery-origin fish on the natural spawning grounds in multiple spring-run populations elevate the risks of long-term genetic impacts, although some of these programs may also provide some demographic benefits.

Extinction Risk Assessments

The SRT's determination of overall risk to the OC and SONCC Chinook salmon ESUs used the categories of "high risk" of extinction, "moderate risk" of extinction, or "low risk" of extinction. The high and moderate risk levels were defined in a prior review of OC coho salmon, and have also been used for recent status updates of all listed salmon and steelhead ESUs.

They are defined as follows:

- **High risk:** A species or ESU with a high risk of extinction is at or near a level of abundance, productivity, diversity, and/or spatial structure that places its continued existence in question. The demographics of a species/ESU at such a high level of risk may be highly uncertain and strongly influenced by stochastic and/or depensatory processes. Similarly, a species/ESU may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction, modification, or curtailment of its habitat; disease epidemic) that are likely to create such demographic risks.
- **Moderate risk:** A species or ESU is at moderate risk of extinction if it exhibits a trajectory indicating that it is more likely than not to reach a high level of extinction risk in the foreseeable future. A species/ESU may be at moderate risk of extinction due to projected threats and/or declining trends in abundance, productivity, spatial structure, or diversity. The appropriate time horizon for evaluating whether a species or ESU is more likely than not to become at high risk in the future depends on various case- and species-specific factors. For example, the time horizon may reflect certain life-history characteristics (e.g., long generation time or late age-at-maturity) and may also reflect the timeframe or rate over which identified threats are likely to impact the biological status of the species or ESU (e.g., the rate of disease spread). The appropriate time horizon is not limited to the period that status can be quantitatively modeled or predicted within predetermined limits of statistical confidence.
- **Low risk:** Neither at high nor moderate risk of extinction.

The overall extinction risk determinations reflect the informed professional judgment of each SRT member. This assessment was guided by the results of a risk matrix analysis integrating information about demographic risks with expectations about likely interactions with threats and other factors. Following prior reviews, the team considered the foreseeable future to be a time period of 30–80 years.

In addition to assessing the risk status of each ESU as a whole, the team also evaluated whether there were significant portions of the range (SPR) of each ESU that are at either moderate or high risk of extinction. In doing this, the team followed advice from the NMFS West Coast Region and NMFS Office of Protected Resources on how to interpret the phrase "significant portion of its range" in light of the 2014 joint Fish and Wildlife and NOAA SPR policy (USOFR 2014) and subsequent legal rulings.

The SPR analysis involved identifying and evaluating portions of each ESU that are potentially at moderate or high risk of extinction and are important to the ESU's overall long-term viability, yet not so important as to be determinative of its current or foreseeable status. In other words, the goal of the SPR evaluation was to determine if there are important portions of the ESU that are currently at high or moderate risk, but that are not so important that their status leads to the entire ESU being currently at high or moderate risk. The rationale for this approach is to ensure that there is a clear distinction between a species (or ESU) that is at risk throughout all of its range and one that is at risk in only a significant portion of its range.

In conducting the SPR analysis, the team considered both previously defined geographic strata and the spring-run component of each ESU, which also makes use of geographically unique habitat, for their potential significance.

OC Chinook salmon ESU

Rangewide extinction risk assessment

The team concluded that the OC Chinook salmon ESU was most likely to be at low risk of extinction. The primary factors leading to the conclusion of low risk included high total abundance—with multiple populations having >10,000 spawners in typical years—and total-ESU abundance, commonly >100,000 spawners. The high total exploitation rates (commonly exceeding 50% for most populations), although a source of some concern to the team, were also cited as evidence of relatively high productivity, because the populations are generally maintaining their abundance despite high harvest rates. The ESU consists of numerous, well distributed spawning populations, presenting few risks associated with spatial structure. The long-term, segregated spring-run hatchery programs in the Tillamook and Nestucca Rivers were considered to be a local risk, as were several of the fall-run programs, but in general the relatively limited hatchery production in the ESU was not considered to be a substantial risk to diversity of the ESU as a whole.

In evaluating threats, most team members concluded that most current factors (habitat, overutilization, inadequate regulations, disease predation, hatchery effects) presented low-to-moderate risks to the ESU. The team noted that there was a long history of land-use practices leading to habitat degradation, but that freshwater habitat has likely been improving slowly over the past several decades due to stricter land-use regulations compared to the early 20th century. The team noted that exploitation rates were quite high, but found that fishery management appeared to be responsive to changes in status, particularly for terminal fisheries. More distant ocean fisheries may be less responsive to local population status.

Potential effects of future predicted climate change are clearly a risk. The team was concerned that rising stream temperatures and lower summer flows would be detrimental to the spring-run life history, since adults spend some or all of the summer in freshwater systems that are predicted to be exposed to higher temperatures, and the spring runs are already at low abundance in most of these rivers. Populations characterized by late-summer/early-fall smolt outmigration may also be more vulnerable than those with early-summer outmigration. The team noted, however, that there remains considerable uncertainty about the localized effects of climate change to these populations, and that predicted future stream temperatures in many of the coastal streams remain within the healthy range for salmon.

SPR extinction risk assessment

ODFW divides the OC Chinook salmon ESU into four geographic strata. These strata are aligned with similar strata NMFS identified in the recovery plan for OC coho salmon. The team evaluated these geographic strata and concluded that each of them met the criteria for being a significant portion of the range of the OC Chinook salmon ESU. The team evaluated the risk status of each of the geographic strata and concluded, with varying degrees of confidence, that all were at low risk of extinction.

For the Oregon Coast, the team concluded that the spring-run life history was not significant to the long-term viability of the ESU, due to the lack of spring run-specific habitat in most of the river systems, the lack of strong evidence that the spring run was ever historically a major component of the ESU, and the likelihood that the fall-run life history is more robust to predicted future climate changes in this ESU. Regardless of the question of its significance, however, the team largely concluded that the spring-run life history was at moderate risk. Risk factors for the spring run included concerns about overall relatively low abundance of spring-run Chinook salmon in the ESU, the very poor status of the South Fork Umpqua River spring-run population, negative effects of straying by the segregated spring-run hatchery programs in the Tillamook and Nestucca River systems, and high vulnerability to future climate change due to warming summer river temperatures.

SONCC Chinook salmon ESU

Rangewide extinction risk assessment

The team concluded the SONCC Chinook salmon ESU was most likely to be at low risk of extinction. Factors supporting this conclusion included its overall high abundance, which has been commonly >50,000 natural spawners for the ESU as a whole, most of which consist of natural-origin fish. This high abundance has been maintained in the presence of relatively high total exploitation rates. Although there are concerns about the status of the spring-run component of the ESU (discussed below), the spring-run life history nonetheless remains present with several thousands of spawners annually in the Rogue River. The fall-run component is spatially spread across multiple populations, most of which typically have natural spawning abundance in the thousands. Environmental and regulatory risks were generally evaluated to be low, while climate risks were evaluated to be moderate.

Despite the overall conclusion of low risk, the team noted that there is a relatively small number of populations in the ESU, with a majority of the ESU's abundance concentrated in the Rogue River. There was also concern about a lack of accurate abundance information for the important Smith River population in California. Exploitation rates were likely higher than optimal for these populations in some years, and there is currently no direct consideration of SONCC Chinook salmon ESU status in setting ocean harvest rates. The effects of future climate change may be quite severe, particularly for the spring-run life history, whose habitat may be differentially vulnerable to high temperatures, lower summer flows, and the effects of increasing wildfires and associated disturbances.

SPR extinction risk assessment

The team identified two major geographic strata in the SONCC Chinook salmon ESU—the Rogue River and the coast streams—and concluded that each was a significant portion of the range of the ESU. In considering the geographic strata, the team concluded that the Rogue River stratum was at low risk. The team concluded that the coastal stratum was at moderate risk. For the coastal stratum, primary concerns were the relatively small sizes and small number of coastal populations, and a lack of adequate monitoring for the Smith River population.

The team concluded that the spring run in the SONCC Chinook salmon ESU was significant to the ESU's long-term viability. The team noted that the spring-run life history was and is a substantial component of the abundance of the Rogue River system, which is by far the largest in the ESU. The spring-run life history is important for the ESU to fully access the habitat in the Rogue River, and might have also been historically important in the Smith River.

The team concluded that the spring-run life history in the SONCC is at moderate-to-high-risk. Risk factors for the spring run included the large decline in the Rogue River in the mid-1990s and lack of subsequent recovery, despite considerable ongoing conservation efforts. Recent average abundance estimated at the former Gold Ray Dam site, for example, was 4,540 natural spawners from 2019–21, below the 5,000-spawner threshold ODFW has identified as indicative of a significant deterioration in status, and a small fraction of the typical abundance prior to 1990. Abundance in 2007 (3,465 natural spawners) was also below ODFW's single-year threshold for significantly deteriorating status. Other risk factors include the near-absence of spring-run Chinook salmon outside of the Rogue River; the ongoing effects of the Lost Creek Dam, which may be increasing geneflow between fall- and spring-run in the Rogue River, with possible negative effects on the spring run; and the vulnerability of spring-run Chinook salmon to the very high summer Rogue River temperatures that are predicted by the end of the century due to climate change.

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Introduction

On 4 August 2022, the National Marine Fisheries Service (NMFS) received a petition (Native Fish Society et al. 2022; henceforth "petition") to list the Oregon Coast (OC) and Southern Oregon/Northern California Coastal (SONCC) Chinook salmon evolutionarily significant units (ESUs) as threatened or endangered under the Endangered Species Act (ESA) or, alternatively, to list only spring-run Chinook salmon in both the OC and SONCC Chinook salmon ESUs as threatened or endangered under the ESA. On 11 January 2023, NMFS announced a 90-day finding on the petition, determining that the petitioned action may be warranted (USOFR 2023).

On 6 January 2023, the NMFS West Coast Region (WCR) requested that the Northwest Fisheries Science Center (NWFSC) conduct an analysis and review of the petition's claim that OC and SONCC Chinook salmon ESUs are at risk of extinction and warrant listing as a threatened or endangered species under the ESA. NMFS had previously completed an ESU configuration analysis of OC and SONCC spring-run Chinook salmon populations in response to two petitions to list only the spring-run component of these ESUs (Ford et al. 2021) to evaluate whether OC and/or SONCC spring-run Chinook salmon should be considered ESUs. To make this evaluation, the panel compiled the best available scientific and commercial information, including consideration of information received in response to both 90-day findings, and had announced a finding that listing was not warranted (USOFR 2021b). NMFS determined that the OC and SONCC spring-run Chinook salmon populations do not meet the ESU policy criteria to be classified as ESUs separate from the OC and SONCC fall-run Chinook salmon populations and, therefore, do not meet the statutory definition of a species under the ESA.

After reviewing the information contained in the 2022 petition, as well as information readily available in agency files, NMFS concluded that the petitioned action to list only the spring-run components of the OC and SONCC Chinook salmon ESUs was not warranted (USOFR 2023). Therefore, this review evaluates only whether the previously identified OC and SONCC Chinook salmon ESUs warrant listing as threatened or endangered species under the ESA.

The purpose of a status review is to synthesize the best available scientific and commercial information regarding the species's status, which includes its life history, demographic trends, and susceptibility to threats, and evaluate the extinction risk of the species. The status review team (SRT) considered the information contained in the petition, public comments received following the 90-day finding on the petition, information solicited from state and tribal agencies, and information in the broader scientific literature.

The rest of this report is organized around the tasks necessary to achieve this goal:

1. Evaluate and, if necessary, update the ESU configuration.
2. Conduct a demographic risk analysis for each ESU.
3. Conduct an analysis of threats related to the ESA Section 4(a)(1) listing factors.
4. Evaluate the extinction risk of the ESUs, based on information in Tasks 2 and 3.
5. Depending on the outcome of Task 4, evaluate the extinction risk based on a "significant portion of its range" (SPR) analysis.

ESU Configuration

NMFS ESU Policy

The ESA allows listing of species, subspecies, and distinct population segments (DPSes) of vertebrates. The ESA as amended in 1978, however, provides no specific guidance for determining what constitutes a DPS. Waples (1991) developed the concept of an ESU for identifying DPSes of Pacific salmon. This concept was subsequently adopted by NMFS in applying the ESA to anadromous salmon species. The NMFS ESU policy stipulates that a salmon population or group of populations is considered a DPS if it represents an ESU of the biological species (USOFR 1991). An ESU is defined as a population or group of populations that 1) is substantially reproductively isolated from conspecific populations, and 2) represents an important component in the evolutionary legacy of the species.

Information that can be useful in determining the degree of reproductive isolation includes incidence of straying, rate of dispersal, degree of genetic differentiation, and the existence of barriers to migration.[1] Insight into evolutionary significance or discreteness can be provided by data on genetic and life-history characteristics, habitat differences, and the effects of stock transfers or supplementation efforts on historical patterns of diversity (Waples 1991).

Description of the Currently Identified OC and SONCC Chinook Salmon ESUs

In the 1990s, NMFS undertook a series of coastwide status reviews of Pacific salmon. These involved identifying ESUs of salmon spawning in U.S. West Coast (California to Washington) rivers and evaluating their ESA risk status (endangered, threatened, or not at risk). Myers et al. (1998) originally described two ESUs that included Chinook salmon spawning in Oregon and California coastal streams: an Oregon Coast ESU containing coastal populations of spring- and fall-run Chinook salmon from the Elk River to the mouth of the Columbia River, and a Southern Oregon and Coastal California ESU containing all spring- and fall-run Chinook salmon spawning in coastal rivers from Cape Blanco south of the Elk River to the southern extent of the species range in California (Figure 1). Based on additional genetic information, the Southern Oregon and Coastal California Chinook salmon ESU was later divided into two separate ESUs, the SONCC ESU and a California Coastal ESU (USOFR 1999b). The SONCC ESU includes Chinook salmon spawning in rivers from Euchre Creek to the Lower Klamath River, and the California Coastal ESU includes the rivers south of that. The OC ESU and the SONCC ESU were determined not to be at risk of extinction either at the time of the review or in the foreseeable future, and have not been listed under the ESA (Myers et al. 1998; USOFR 1999b).

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[1] Note that the ESU policy was developed and applied to salmon populations of the same species that are physiologically capable of interbreeding. The term "reproductive isolation" therefore refers to restricted gene flow for any reason, including, for example, geographic isolation or temporal differences in spawn timing.

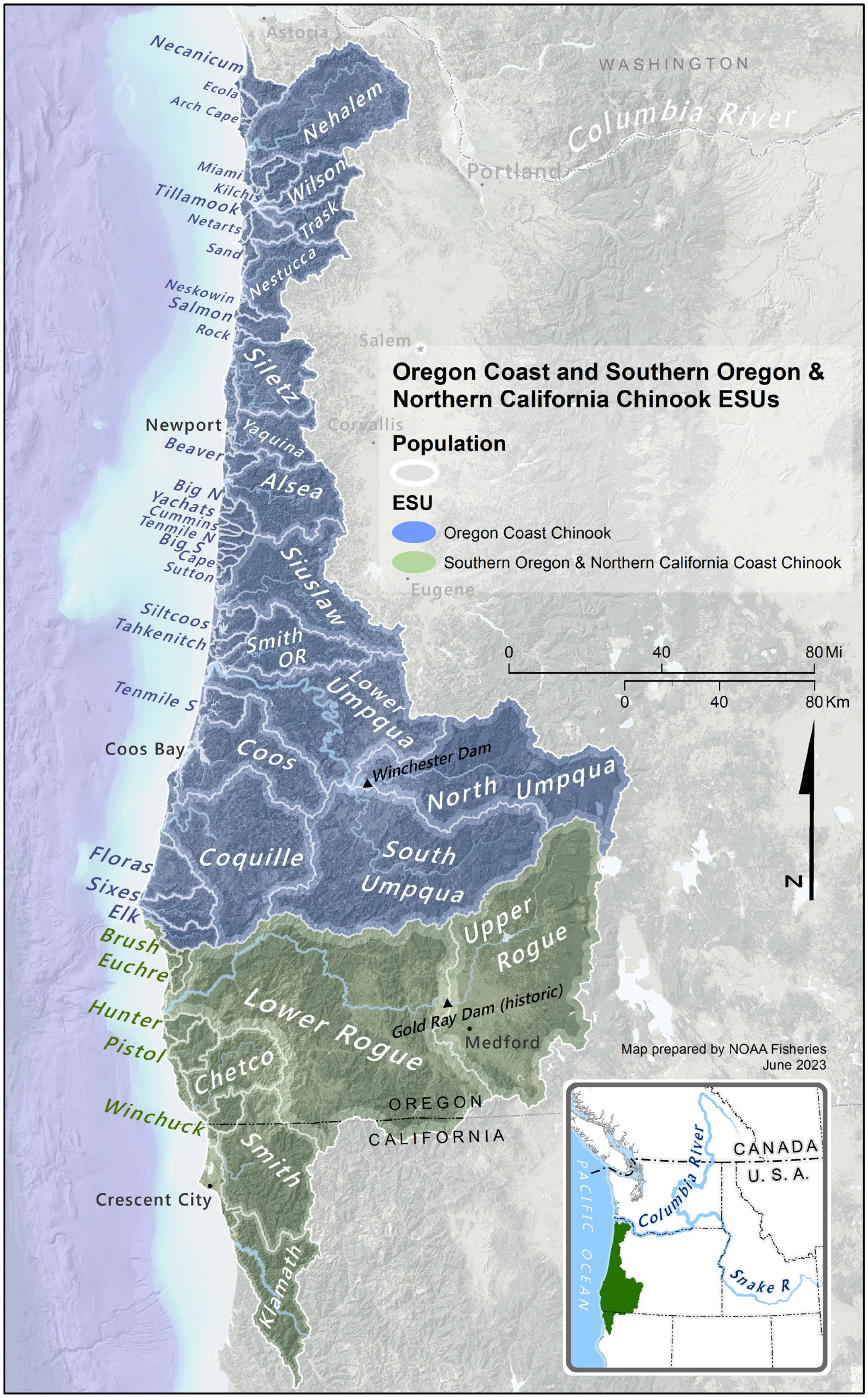


Figure 1. Map of OC and SONCC Chinook salmon ESU rivers and boundaries. Basins with named, major Chinook salmon populations are labeled in white.

Summary of Relevant Data Collected after 1999

The OC and SONCC Chinook salmon ESUs were initially defined in the late 1990s as part of the coastwide status review process undertaken by NMFS. Factors considered included patterns of juvenile and adult life-history variation, freshwater ecological provinces, patterns in ocean distribution, and patterns of genetic variation at individual loci assessed using molecular methods. The SRT reviewed the analyses that identified the current ESU configuration (Myers et al. 1998, USOFR 1999b), and concurred with the conclusions of those analyses based on the data that were available at that time. In the intervening decades, the most marked change in population information has been the analysis of additional genetic variation, along with some updates to information on ocean distribution.

The majority of the genetic information available to the original status reviews in the 1990s was developed using starch-gel electrophoresis of allozymes, which typically involved surveying variation at <50 loci, with typically 2–3 alleles each. Increasingly in the early 2000s, the use of DNA microsatellite and single-nucleotide polymorphisms (SNPs) provided a wealth of additional genetic information. More recently, genomic methods, which survey variation to varying extents throughout the entire genome, have increased the amount of genetic information available by several orders of magnitude (thousands to millions of loci). Thus, the quantity and type of genetic information available to address the issue of ESU and DPS delineation has changed considerably since the time of the original ESA listings.

Genetics studies that included samples from the OC and SONCC Chinook salmon ESUs were recently reviewed as part of a prior status review (Ford et al. 2021) to evaluate whether OC and/or SONCC spring-run Chinook salmon should be considered ESUs. To make this evaluation, the panel compiled the best available scientific and commercial information, including consideration of information received in response to both 90-day findings. That review focused on the question of whether the spring-run component of these populations met the criteria for being a DPS under the NMFS ESU policy, but the same data are relevant for evaluating whether there is any reason to update the geographic boundaries of the currently configured ESUs.

Figure 2 is an example of one of the genetic analyses that informed the original ESU designations. The analysis illustrates that samples of Chinook salmon tend to form geographically discrete genetic clusters based on their rivers of origin. Samples from the central and northern Oregon coast and from the southern Oregon and northern California coasts are discrete from each other and from other coastal populations to the north or south. The report did note that one Oregon coast sample—spring-run Chinook salmon from the Rock Creek Hatchery in the Umpqua River system (Sample 41 in the figure)—clustered with the southern Oregon/northern California samples. A subsequent follow-up analysis (BRT 1999) included additional California coast samples, and helped support the designation of a California Coastal Chinook salmon ESU separate from SONCC.

As summarized in Ford et al. (2021), an additional five studies were published subsequent to 1998–99 that included coastwide samples of Chinook salmon analyzed for genetic variation at either microsatellite or SNP loci, or a combination of both. These studies support the general pattern of genetic clustering into geographic units that was found in the 1998–99 status reviews. A representative example from one of these studies is illustrated in Figure 3.

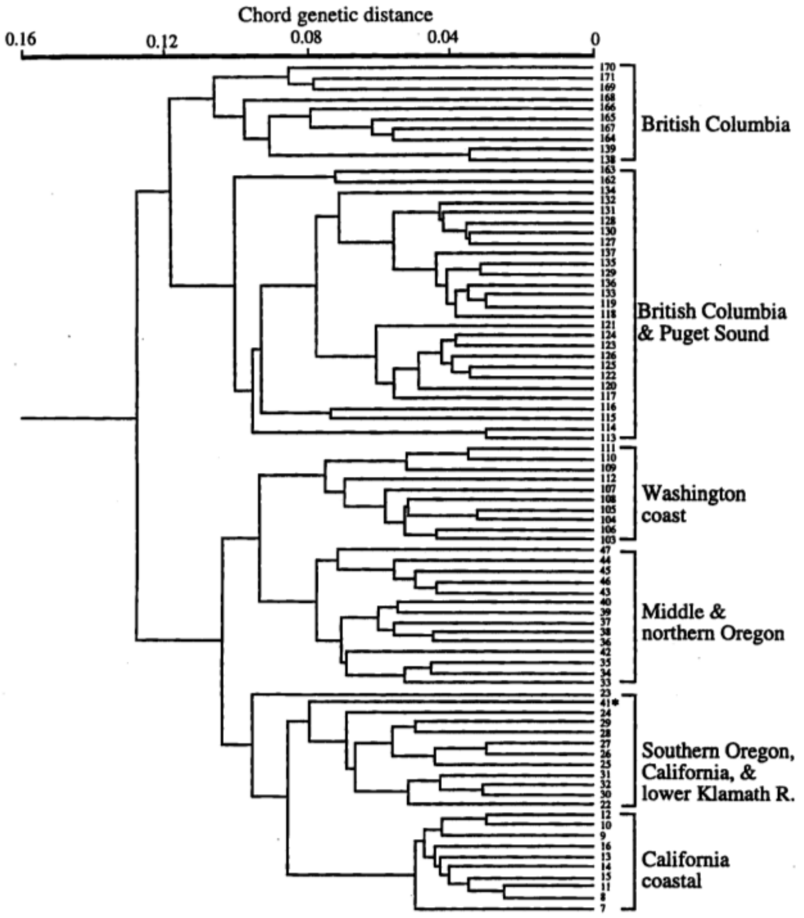
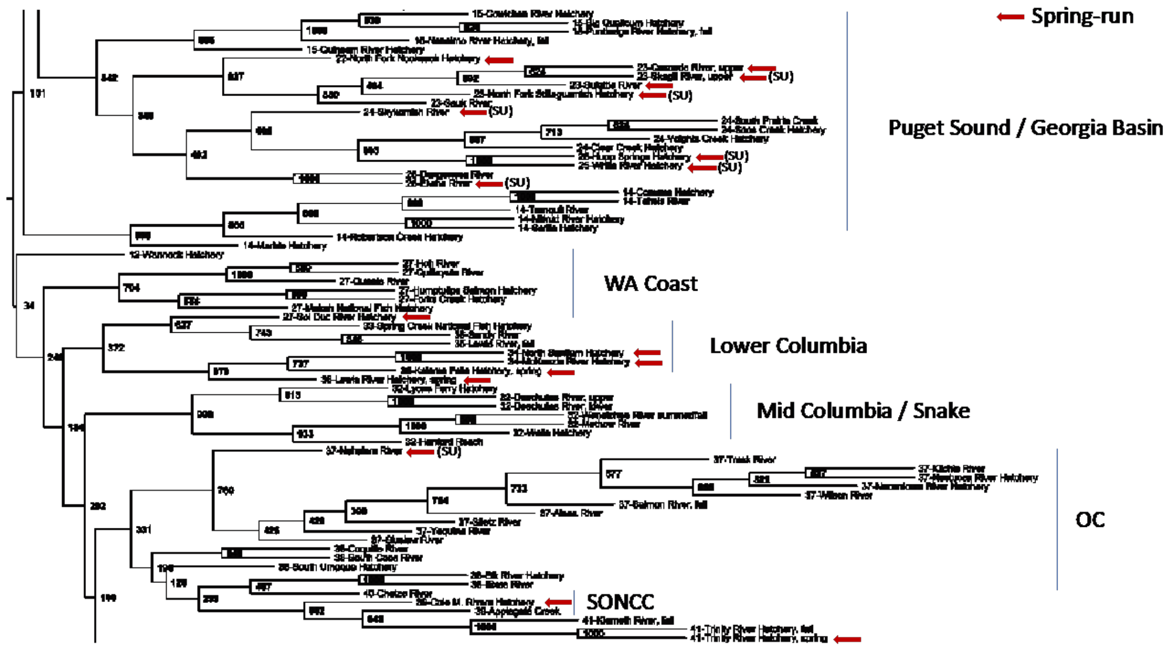


Figure 2. Unweighted pair group method with arithmetic averages (UPGMA) tree of Cavalli-Sforza and Edwards (1967) chord distances based on 31 allozyme loci between 83 composite samples of Chinook salmon, reproduced from Myers et al. (1998, their Figure 20). Designations for the Oregon and Northern California samples are as follows (R. = river, H = hatchery): 22 = Blue Creek, 23 = Omagar Creek H., 24 = Rowdy Creek H., 25 = Smith R., 26 = Winchuck R., 27 = Chetco R., 28 = Pistol R., 29 = Hunter Creek, 30 = Cole R. H., 31 = Applegate R., 32 = Rogue River at Gold Hill, 33 = Euchre Creek, 34 = Elk R. and Elk R. H., 35 = Sixes R., 36 = Coquille R., 37 = Bandon H., 38 = Millicoma R., 39 = Morgan Creek H., 40 = Noble Creek H., 41* = Rock Creek H. spring-run, 42 = Rock Creek H. fall-run, 43 = Siuslaw R., 44 = Alsea R., 45 = Fall Creek H., 46 = Trask H., 47 = Nehalem R. Samples 30, 41, and 47 are spring- or summer-run; all others are fall-run. See Myers et al. (1998, their Table 3) for additional details.

There are several points that are worth noting in Figure 3. The broad pattern of geographic clustering of samples is readily apparent, and generally consistent with that in Myers et al. (1998). However, the congruence between the genetic relationships and the currently defined ESU structure is not perfect, particularly for the OC and SONCC ESUs. Similar to the allozyme-based analysis in Myers et al. (1998), the Umpqua River sample does not cluster with the more northerly Oregon coast samples but rather is (slightly) more similar to samples from the SONCC. In this dataset, the samples from the Elk and Sixes Rivers also form a cluster with SONCC samples, rather than OC.

The tendency of samples from the Umpqua River (most often from the Rock Creek Hatchery) to be more genetically similar to samples from the SONCC than to samples from the OC is apparent across all published datasets in which it is included (Myers et al. 1998, Waples et al. 2004, Seeb et al. 2007, Narum et al. 2008, Moran et al. 2013, Clemento et al. 2014, Hecht et al. 2015). It is important to note that several of these studies used a common set of samples from Rock Creek Hatchery, so the results are not wholly independent (see Ford et al. 2021 for more details). One published study included a fall-run sample from the Umpqua River, and that sample clustered with northern OC samples (Beacham et al. 2006).



Moran et al. (2013)

Figure 3. Reproduction of supplemental figure from Moran et al. (2013), with spring-run samples from coastal Chinook salmon ESUs identified by red arrows. Shown is a partial neighbor-joining tree (focusing the coastal areas of interest) based on Cavalli-Sforza and Edwards (1967) chord distances computed from 13 microsatellite loci.

As part of this review, we reanalyzed the data from Clemento et al. (2014) to focus on the patterns of genetic variation among OC and SONCC samples. These data consisted of genotypes at 96 SNPs, and included 11 OC and SONCC populations among the larger coastwide dataset. We analyzed the data using both a population clustering method—a neighbor-joining tree based on Cavalli-Sforza and Edwards (1967) chord distances (Figure 4)—and a principal components analysis of variation among individuals (Figure 5). In both analyses, the genetic similarity of the Umpqua River spring-run sample (Rock Creek Hatchery) to samples from the SONCC (Cole Rivers, Applegate Creek) is readily apparent.

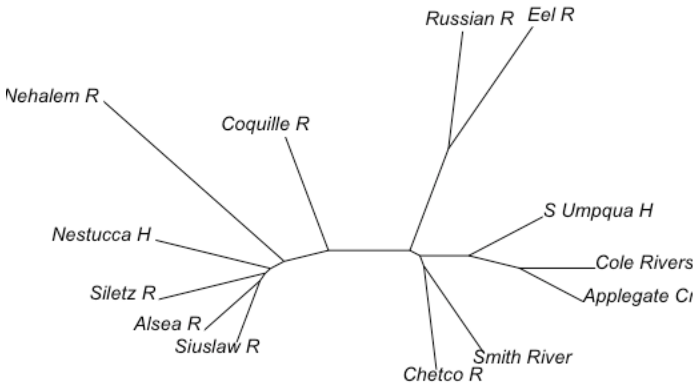


Figure 4. Neighbor-joining tree based on Cavalli-Sforza and Edwards (1967) chord distances for OC, SONCC, and California Coastal samples, based on genotype data from Clemento et al. (2014). *S Umpqua H* refers to spring Chinook salmon from the Rock Creek Hatchery.

Recently, Dr. Kathleen O'Malley (Oregon State University, personal communication) analyzed >1000 Chinook salmon sampled from the OC and SONCC in 2020 and 2021 for a panel of genome-wide SNP loci and a selection of loci on chromosome 28 known to

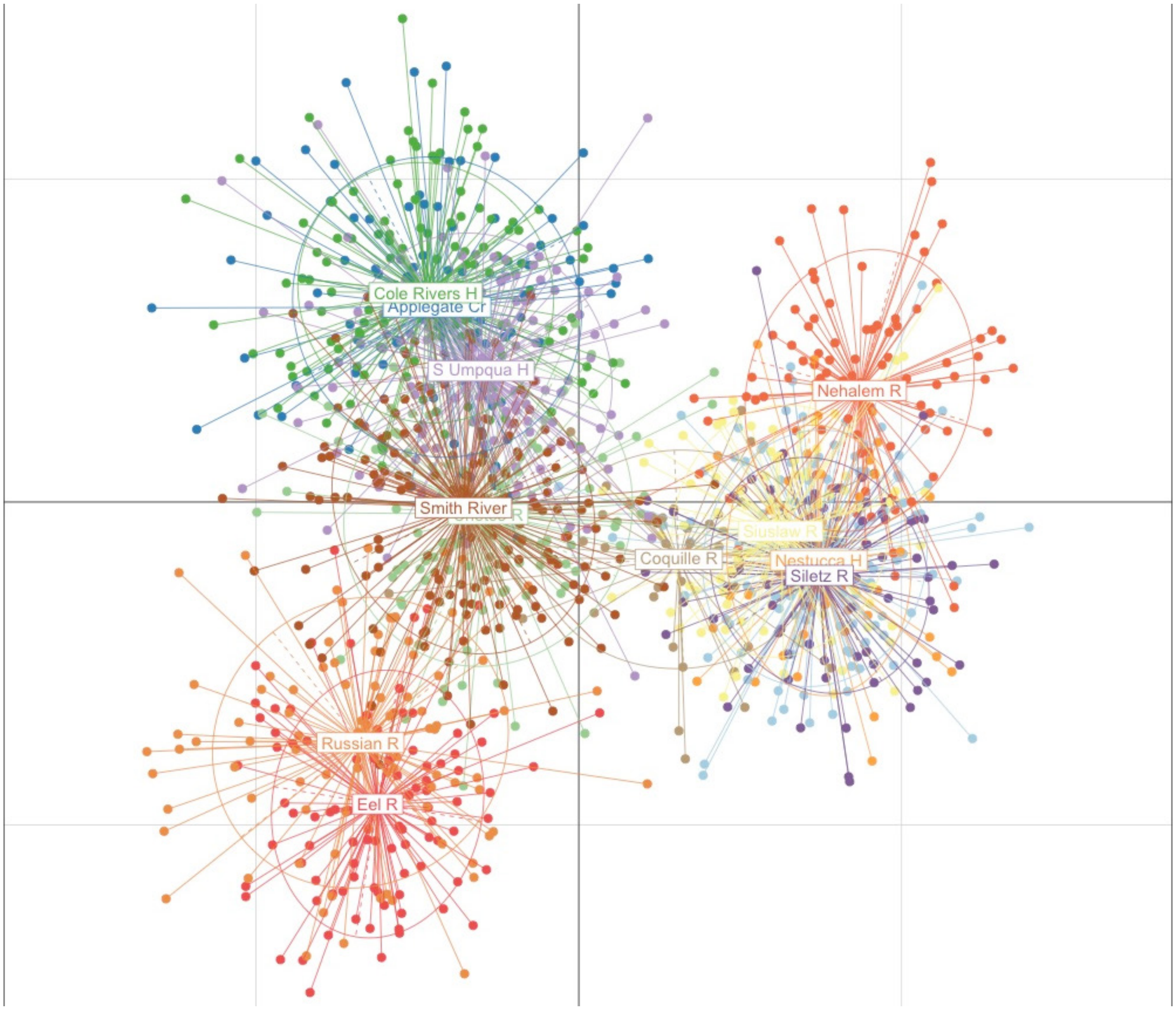


Figure 5. Principal components plot of genetic samples from OC, SONCC, and California Coastal streams, based on data from Clemento et al. (2014). The obscured label behind the Smith River is the Chetco River.

be associated with run timing variation. This analysis is particularly informative, since it focuses on recent samples of natural-origin, spring- and fall-run fish from multiple OC populations. Although the analysis is preliminary and the sample sizes are small for some categories, there are several notable patterns apparent in the data (Figure 6).

First, the Rogue River (SONCC) sample is clearly differentiated from most of the OC samples. Second, the spring- and fall-run samples from the Rogue River are not differentiated from each other. Both of these patterns are consistent with previously published analyses. Third, the Umpqua River spring-run sample overlaps with both the Rogue River sample (spring and fall) and a portion of the OC samples, while the Umpqua River fall-run sample overlaps nearly entirely with the northern OC samples. This pattern is also generally consistent with previously published analyses, but this is the first dataset to contain both spring- and fall-run samples from the Umpqua River. Fourth, within the OC group, spring- and fall-run samples are generally more differentiated from each other than is the case in the Rogue River. This is

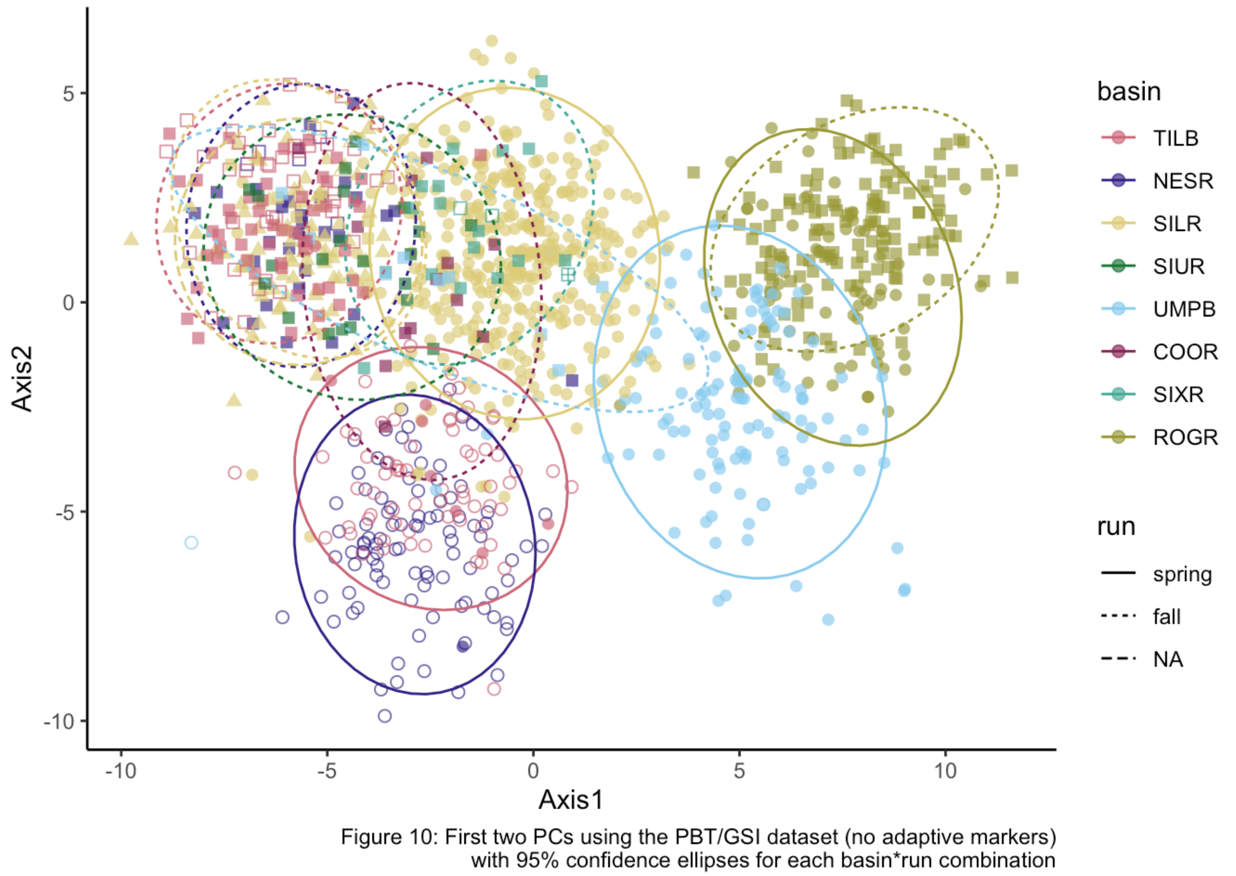


Figure 6. Principal components analysis of variation at 238 "neutral" loci (GREB1L markers are not included) from seven OC sites and the Rogue River (SONCC). Circles indicate spring-run, squares are fall-run, and triangles are unknown run timing. Filled points indicate natural-origin fish; open points = hatchery-origin fish. TILB = Tillamook River basin, NESR = Nestucca River, SILR = Siletz River, SIUR = Siuslaw River, UMPB = Umpqua Rivber basin, COOR = Coos River, SIXR = Sixes River, ROGR = Rogue River. Figure and analysis courtesy of K. O'Malley (Oregon State University).

particularly true in the samples from the Tillamook and Nestucca Rivers, where hatchery-origin spring-run Chinook salmon are notably distinct from the natural- and hatchery-origin fall-run samples. In contrast, natural-origin spring-run Chinook salmon from the Siletz River are similar to other northern OC populations, and overlap with Siletz fall-run samples.

Ocean Distribution

Differences in ocean distribution were another type of data used by Myers et al. (1998) to differentiate the OC and SONCC Chinook salmon ESUs. We use published analyses of coded wire tag (CWT) recoveries from ocean fisheries to describe spatial differences among rivers in CWT recoveries and estimated ocean distributions (Weitkamp 2010, Shelton et al. 2019, 2021), notably as prey for marine mammals. We construct the first coastwide state–space model for fall Chinook salmon tagged fish released from California to British Columbia between 1977 and 1990 to estimate seasonal ocean distribution along the west coast of North America. We incorporate recoveries from multiple ocean fisheries and allow for regional variation in fisheries vulnerability and maturation. We show that Chinook salmon ocean distribution depends strongly on region of origin and varies seasonally, while survival shows regionally varying temporal patterns. Simulations incorporating juvenile production data provide proportional stock composition in different ocean regions and the first coastwide projections of Chinook salmon aggregate abundance. Our model provides an extendable framework that can be applied to understand drivers of Chinook salmon biology (e.g., climate effects on ocean distribution).

From Shelton et al. (2021) we extracted estimates of ocean distribution for Elk River and Salmon River fall-run stocks (Figure 7). Spatial areas follow codes from Shelton et al. 2021 (Figure 8) and span from Monterey, California (MONT), to northern southeastern Alaska (NSEAK). Panels show proportional distributions for each stock during the summer and fall seasons (Figure 7). Estimated ocean distributions are derived from a population dynamic model that uses CWT and fishing effort for commercial and recreational fleets from California to Alaska (see Shelton et al. 2019, 2021). Both the Elk and Salmon River stocks are known as far-north migrating Oregon Chinook salmon (CTC 2022c), and both are found predominantly in British Columbia and Alaska during the summer, with more fish present off Oregon during the fall in anticipation of the freshwater spawning migration.

For the SONCC Chinook salmon ESU, Weitkamp (2010) included two groups released from the Rogue River (a spring-run and a fall-run stock; Figure 9). For comparison, patterns of CWT recoveries for more northern and more southern ESUs are presented in Figure 10. CWT recoveries from the Rogue River appear very similar to spring- and fall-run releases from the Klamath River.

Weitkamp (2010) provides ocean recoveries of additional CWT groups from the OC Chinook salmon ESU. The main distinction between the methods of Shelton et al. (2019, 2021) and Weitkamp (2010) is that the former attempted to account for fisheries effort and season in their estimates of distribution, while Weitkamp (2010) summarized the distribution CWT recoveries in space over a series of years with high fisheries effort and catch. They also used different years of CWT recovery data: Weitkamp (2010) used CWT recoveries through 2004; Shelton et al. (2021) used data through 2015.

We present Weitkamp's (2010) results for the proportion of CWT recovered by state (Alaska, Washington, Oregon, or California) or province (British Columbia) for four stocks. Two stocks, Elk and Salmon River fall-run, are identical to the stocks used in Shelton et al. (2021; Figure 9), and two stocks (Umpqua River spring-run, Trask River fall-run) are distinct. For comparison, patterns of CWT recoveries for more northern and more southern ESUs are presented as well. There is clearly a strong similarity between CWT recoveries in the Trask and Salmon Rivers (Figure 9). In contrast, the Umpqua River spring-run stock appears to have a more southerly distribution, with a larger proportion of CWT recoveries in California and Oregon than other Oregon Coast CWT stocks. Elk River CWT recoveries are intermediate between Salmon River fall-run and Umpqua River spring-run CWT recoveries, and are strongly influenced by a directed fishery near the mouth of the Elk River. Chinook salmon from the Umpqua River also show a younger ocean age structure (Figure 11), more similar to Chinook salmon from SONCC populations than other OC populations.

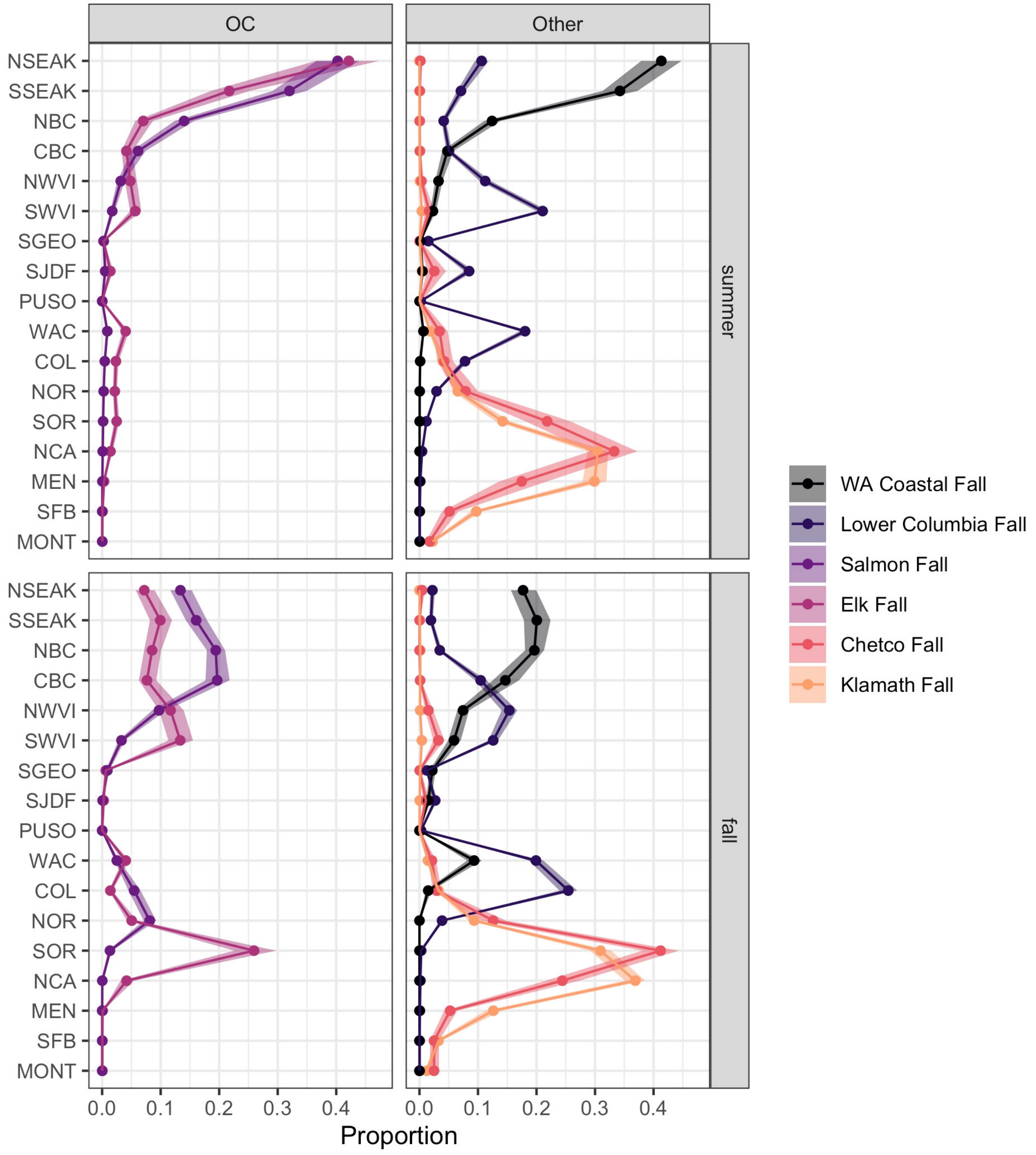


Figure 7. Ocean distribution estimates for two OC fall-run stocks (Elk River and Salmon River) in two seasons (summer [Jun–Jul] and fall [Aug–Oct]) from CWT Chinook salmon released in the Elk and Salmon Rivers (all based on recoveries between 1979 and 2015). The y-axis shows spatial areas between MONT and NSEAK (see Figure 8). For comparison, we show estimated distributions for four other Chinook salmon groups from Washington Coast, Lower Columbia River, SONCC (Chetco River), and UKTR (Klamath River). These are proportional distributions (proportions for each season-origin combination sum to one) for the among-year average distribution.

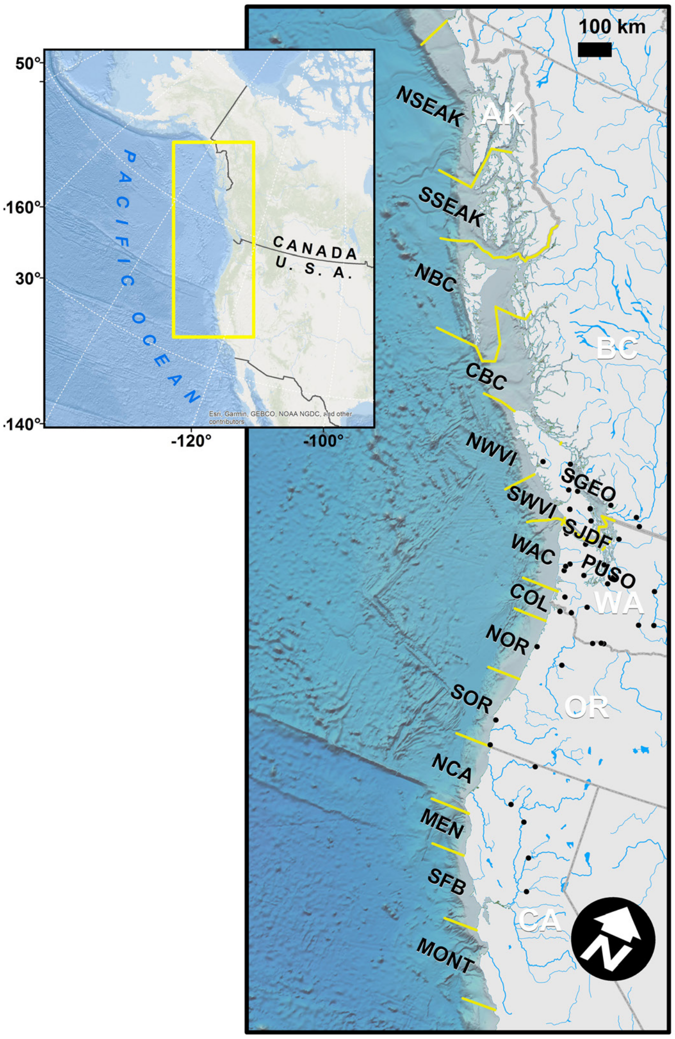


Figure 8. Map of ocean areas used for distribution estimates (from Shelton et al. 2021).

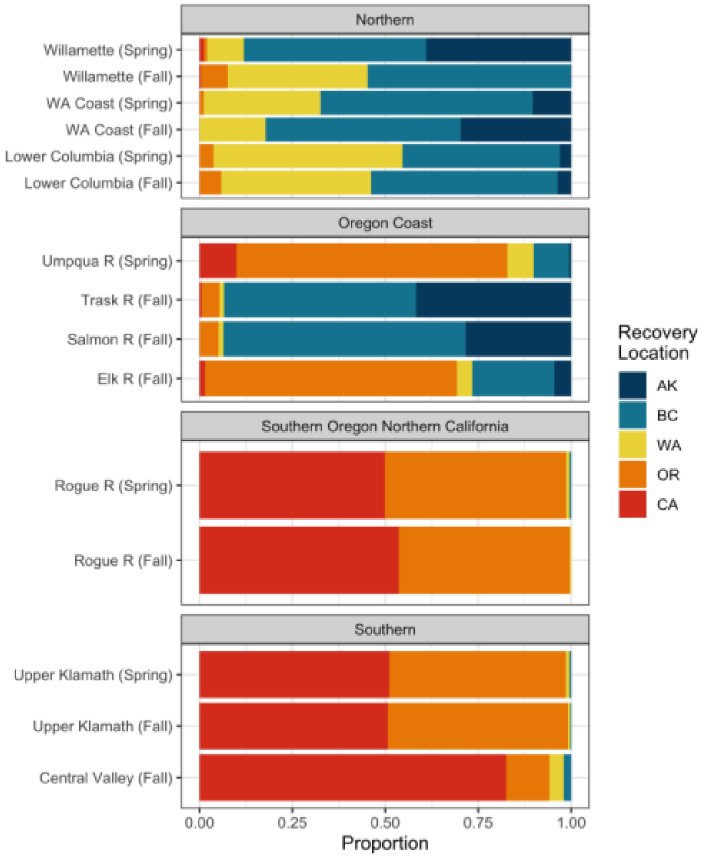


Figure 9. Proportional distribution of ocean CWT recoveries by state/province for OC Chinook salmon. Run type is noted along with river of origin. Recoveries of CWT from more northern (Columbia River, Washington Coast) and more southern rivers (SONCC and California's central valley) are shown. See Weitkamp (2010) for methodological details. Note that the high proportion of recoveries of Elk River fish in Oregon is due to a fall season terminal fishery focused on that population.

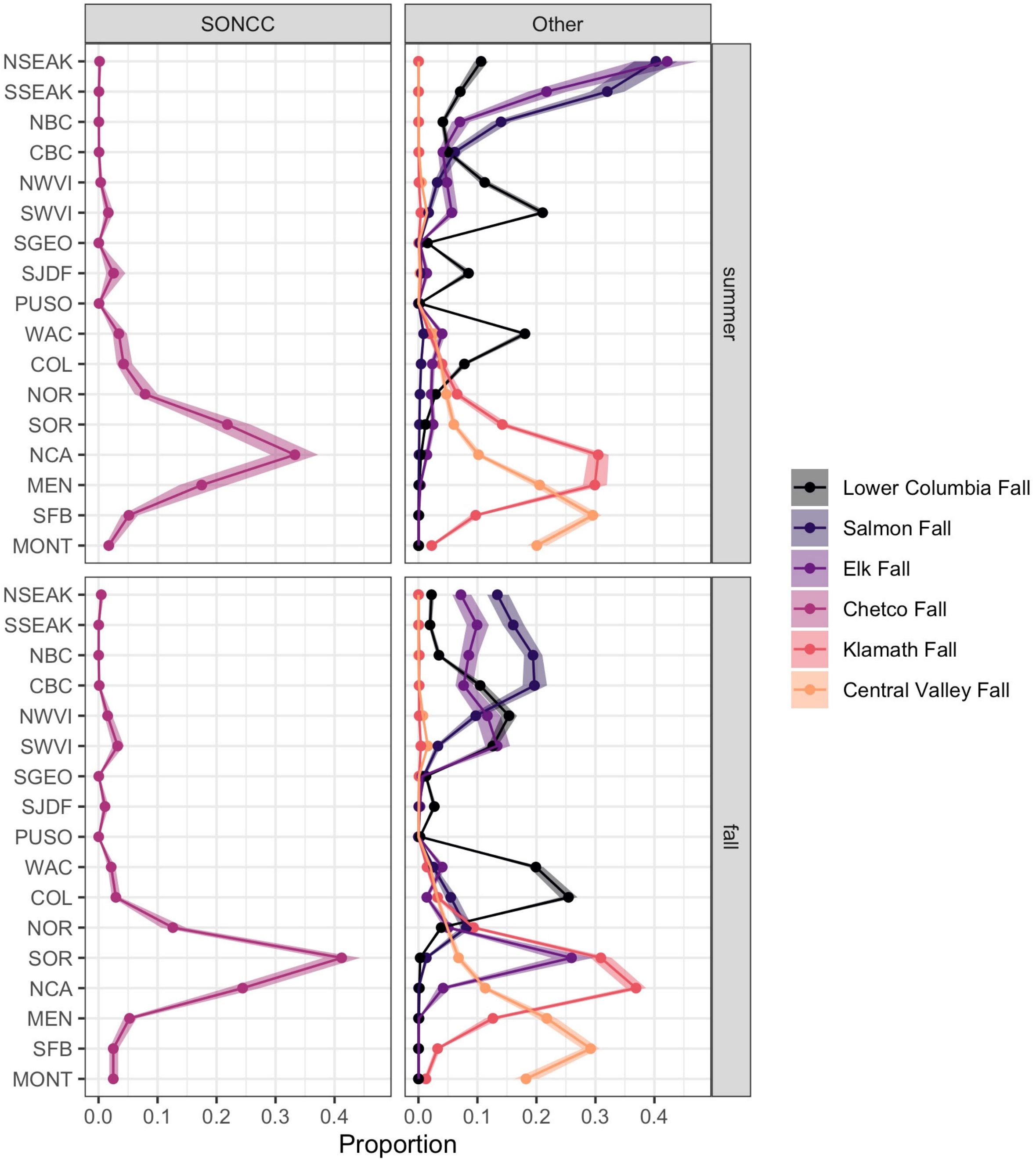


Figure 10. Ocean distribution estimates for fall-run stocks in two seasons (summer [Jun–Jul] and fall [Aug–Oct]) from CWT Chinook salmon released in the Chetco River (all based on recoveries between 1979 and 2015). The y-axis shows spatial areas between MONT and NSEAK (see also Figure 11). These are proportional distributions (proportions for each season-origin combination sum to one) for the among-year average distribution.

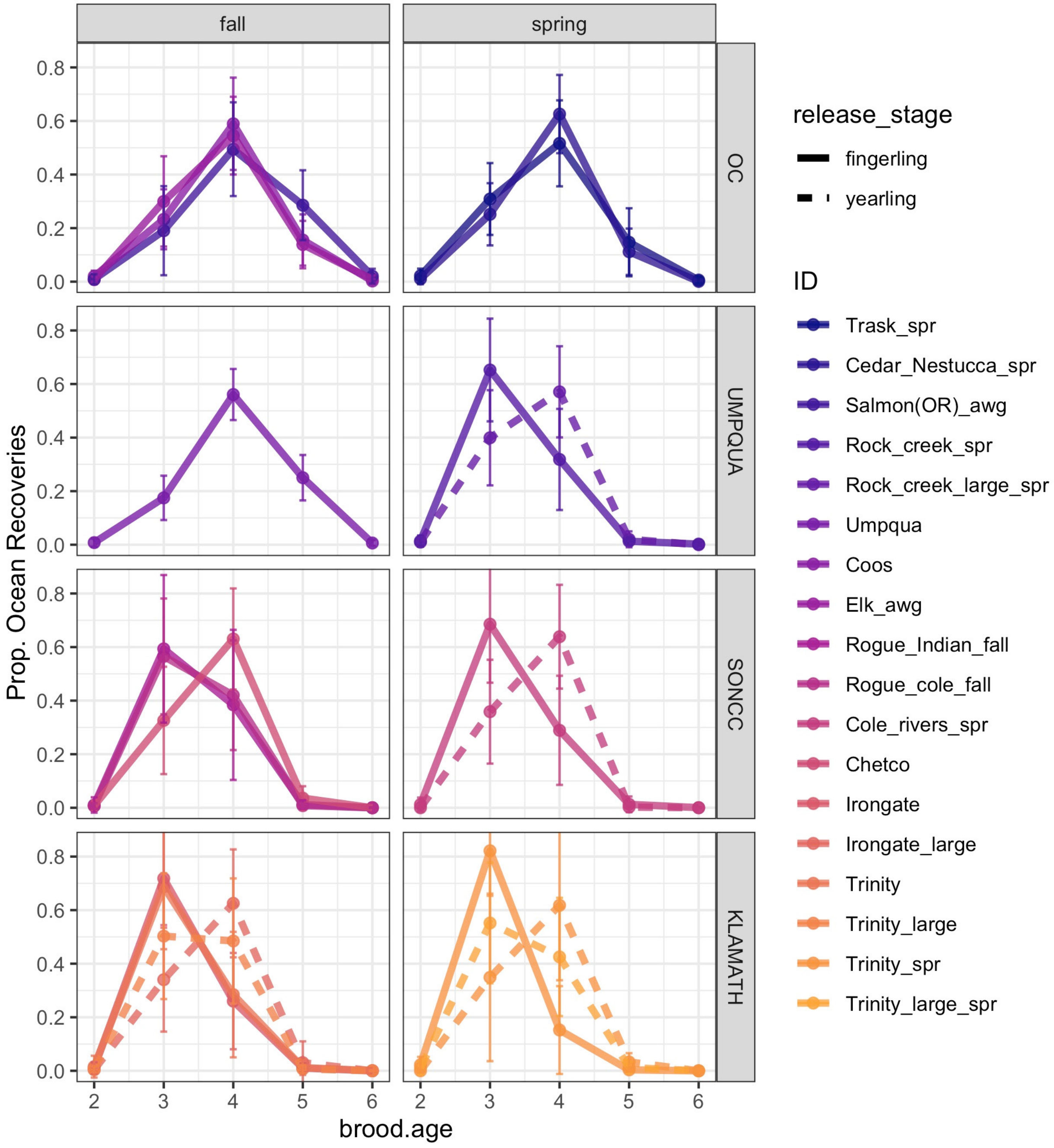


Figure 11. Proportion of marked hatchery release groups captured in the ocean, by age and ESU. Facets are sorted by geography (north to south) and run timing. Solid lines indicate sub-yearling releases; dashed lines indicate yearling releases.

The Chetco River fall-run stock is found predominantly off Oregon and northern California in both the summer and fall. Ocean distribution for SONCC Chinook salmon appears similar to ocean distribution of Chinook salmon from the Klamath river.

In addition to the questions about the OC/SONCC ESU boundary raised by the genetic and ocean distribution data summarized above, there is also some updated information related to the boundary between SONCC and the Upper Klamath–Trinity River (UKTR) Chinook salmon ESU. Kinziger et al. (2013) evaluated genetic variation among 13 population samples from the Klamath River basin. The current boundary between the SONCC and UKTR ESUs is placed at the confluence of the Trinity River (USOFR 1999b). The genetic patterns described by Kinziger et al. (2013) are consistent with this boundary, with the exception of the sample from Horse Linto Creek. Horse Linto Creek is a small tributary of the Trinity River above the confluence of the Trinity River with the Klamath River, but the Horse Linto Creek sample is more genetically similar to SONCC samples from streams below the Trinity River confluence.

Current Hatchery Stocks

Artificial propagation efforts for Chinook salmon in these ESUs began in the late 1890s. By the early 1900s, there were hatcheries or egg-taking stations on most of the larger streams along the Oregon coast, especially the Yaquina, Alsea, Siuslaw, Umpqua, Coos, and Coquille Rivers (Cobb 1930, Wahle and Smith 1979). Before 1960, a substantial portion of the Chinook salmon introduced into river basins in the OC Chinook salmon ESU came from lower Columbia River (LCR) fall- and spring-run Chinook salmon stocks—mostly from the Bonneville and Clackamas Hatcheries (see summary in Myers et al. 1998).

Legislation enacted in the mid 1970s allowed the establishment of privately operated, for-profit hatcheries in Oregon (Wahle and Smith 1979). Private facilities operated in the Coos River and Yaquina River basins until 1988 and 1989, respectively (Myers et al. 1998). These salmon ranching operations released millions of smolts produced from spring- and fall-run broodstock primarily obtained from Oregon coastal rivers such as the Rogue, Trask, and Yaquina (NRC 1996). In addition, a number of smaller cooperative hatcheries, built to restore depleted populations, are responsible for a substantial proportion of the current hatchery production.

Since the 1990s, efforts by ODFW to utilize locally derived stocks in artificial propagation programs may have reduced deleterious interactions between hatchery and wild fish, provided that local stocks have not been genetically altered by previous non-native introductions. At the time of the last ESA status assessment (Myers et al. 1998), it was estimated that, overall, the proportion of fall-run hatchery-origin fish spawning naturally in the Oregon Coast Chinook salmon ESU was less than 10% (Kostow 1995). However, spring-run populations were an exception, with hatchery-origin spring-run adults making up the majority of naturally spawning spring-run fish in many areas.

Here, we present information on the existing hatchery stocks currently in use, which reflects current hatchery practices; see Myers et al. (1998) for a thorough review of historical hatchery information. In the description below, we follow ODFW's broad use of the terms “segregated” and “integrated,” in which a segregated stock refers to a hatchery population that incorporates few or no natural-origin fish into the broodstock on a regular basis. An integrated stock, in contrast, refers to a stock in which at least some natural-origin fish are regularly used in the broodstock. Stocks described this way may not necessarily meet the conservation guidelines for integrated and segregated stock defined by other organizations (e.g., Mobrand et al. 2005).

Nestucca River

Spring run (Cedar Creek Hatchery Stock 47)

Cedar Creek Hatchery was originally constructed in 1924. It is likely that spring Chinook salmon releases have occurred in the Nestucca River basin at least periodically since the 1920s. Wallis (1963a) reported that spring-run Chinook salmon eggs from the Nestucca River basin were incubated and reared at the Trask River Hatchery, with the fish subsequently liberated in the Nestucca River, in the late 1920s and early 1930s. It is unclear if the fish transferred to the Nestucca River basin were descendants of adults collected from the Nestucca River basin, of Trask River origin, or a combination of the two. Historical records from Cedar Creek Hatchery indicate that the majority of releases originated from the Nestucca River and Trask River Hatchery. However, releases of Chinook salmon occurred during the late 1950s—although the run-timing was not identified. Spring Chinook salmon are first specifically identified in release records in 1962, and releases of spring Chinook have occurred annually since 1968. Since 1975, the hatchery stock is run as a “segregated” program, with few if any natural fish incorporated into broodstock (Table 1).

Fall run

Historical records for Cedar Creek Hatchery are incomplete. The records do indicate that Chinook salmon from the lower Columbia River and Oregon coast were released in 1955 through 1959, but do not specify the run timing. Fall Chinook salmon smolt releases appear annually beginning in 1975. Cedar Creek Hatchery operated a fall Chinook salmon program until 1993 when it was terminateD.Cedar Creek Hatchery fall-run Chinook salmon were released into the Necanicum, Nehalem, Trask, and Three Rivers (Myers et al. 1998). The current cooperative program (Cedar Creek Hatchery/Rhoades Pond) started with adult collection in the fall of 1999. The first smolt releases were in August 2000.

Salmon River fall run

Returning hatchery adult Chinook salmon are captured at Salmon River Hatchery and used for broodstock. Records (although likely incomplete) do not indicate the release of any non-native fall-run Chinook salmon into the Salmon River basin. According to the Hatchery and Genetic Management Plan (HGMP), the hatchery fall Chinook salmon program’s goal is to have the hatchery fish mimic the characteristics of the wild fall Chinook salmon population. This includes using 50% wild fish each year for broodstock, along with hatchery fish. The broodstock goal has been met in two of the last five years.

Table 1. Summary of current hatchery programs for OC Chinook salmon. Data compiled from hatchery report located here: www.dfw.state.or.us/fish/crp/coastal_multispecies.asp. Data are from 2014 to 2019.

Hatchery program	Location of juvenile releases	Avg. # juveile releases/yr	Avg. % adipose finclipped	Type of broodstock[a]	Avg. proportion unmarked fish in brood	Proportion of hatchery fish on natural spawning grounds[b]
Coquille River Fall Chinook	Coquille River	136,000	100	integrated	0.44	0.02
Coos River Fall Chinook	Coos River	1,800,000	99	integrated	0.00	0.19
North Umpqua River Spring Chinook	North Umpqua River	200,000	100	integrated	0.18	0.50
Umpqua River Fall Chinook	Umpqua River (estuary)	84,000	77	integrated	0.35*	0.02
Salmon River Fall Chinook	Salmon River	200,000	100	integrated	0.31	0.48
Nestucca River Spring Chinook	Nestucca River	241,000	100	segregated	0.00	0.77
Nestucca River Fall Chinook	Nestucca River	106,000	97	integrated	0.23[c]	0.11
Trask River Fall Chinook	Trask River	152,000	100	integrated	0.14	0.02
Trask River Fall Chinook	Necanicum River	25,000	100	segregated	0.14	no data
Trask River Spring Chinook	Trask River	400,000	100	segregated	0.03[c]	0.61

[a] In relation to population where hatchery fish were released.

[b] Recent estimates.

[c] These numbers updated by M. Varney (ODFW, personal communication to L. Kruzic, NMFS) on 8 November 2022.

Trask River

Spring run

Available reports (Wallis 1963a) indicate that egg take of spring Chinook salmon began in 1907, although the hatchery location at that time was approximately three miles upriver of its current location. The hatchery at the current location became operational in 1914 and since then it has operated continuously. Records indicate that, in addition to releases of Trask River-origin juveniles, additional spring-run Chinook salmon from the "Lower Columbia River/Oregon Coast Mix" and the Nestucca, Rogue, and Umpqua Rivers were released into the Trask River (Myers et al. 1998). It is considered a segregated program by ODFW, with few or no natural fish regularly incorporated into the broodstock (Table 1).

Fall run

Available reports (Wallis 1963a) indicate that egg take of fall Chinook salmon began in 1906, although the hatchery location was approximately three miles upriver of its current location. The majority of fall-run releases were derived from adults returning to the Trask River; however, there were considerable transfers from the "Lower Columbia River/Oregon Coast Mix" (Myers et al. 1998). The hatchery at the current location became operational in 1914 and has operated continuously since. With an average of 14% natural-origin fish in the broodstock annually, ODFW considers this to be an integrated program (Table 1).

Elk River fall run (Stock 38)

The Elk River Hatchery program began in 1968 with the collection of fall-run Chinook salmon for broodstock. The first smolts were released in 1969. Records indicate there have been few transfers of fall-run Chinook salmon from outside sources into the Elk River basin, although some sources were categorized as "unknown" (Myers et al. 1998). Collection and spawning of Elk River fall Chinook salmon used native Elk River Chinook broodstock representing historic age and run-timing characteristics inherent to the stock. According to the HGMP, no purposeful or inadvertent selection has been applied to change characteristics of the founding broodstock.

Umpqua River

Spring run (Rock Creek Stock 55)

The Umpqua River spring-run Chinook salmon program at Rock Creek began in 1950 and has been ongoing to this date. The first returns of hatchery spring Chinook salmon to Rock Creek Hatchery occurred in 1952, and have continued to the present day. The broodstock initially collected for the Rock Creek Hatchery on the North Fork Umpqua River may have been influenced by introductions of Rogue River spring-run Chinook salmon in 1951. Low returns of adult spring-run Chinook salmon over Winchester Dam (RKM 116) from 1946–48 (average:

2,404) prompted the release of 35,524 and 3,270 yearling spring-run Chinook salmon from the Rogue and Imnaha Rivers, respectively (ODFW 1954). Although the number of fish released was small during this period, the hatchery fish released into the Rogue River contributed 20.9% and 12.6% of the total adult run in 1953 and 1954, respectively, due to their large size at release (ODFW 1954). Prior to the initiation of the present-day Rock Creek Hatchery Program, there were transfers of spring-run Chinook salmon from the Rogue and Trask Rivers (Wallis 1963a).

Presently, the primary source of broodstock for the spring Chinook salmon program is naturally produced North Umpqua River adults. Hatchery spring Chinook salmon returning to Rock Creek Hatchery are incorporated into the brood per the guidelines established by the Fish Hatchery Management Policy.[2]

Fall run (Stock 151)

Prior to 1997, naturally produced South Umpqua River (Stock 18) fish were used for this program. There have been some transfers into the Umpqua River basin from non-native sources, including Columbia River and other Oregon coast tributaries (Myers et al. 1998). From 1997 until 2000, the progeny were produced from lower Umpqua River brood (Stock 151) and were over 90% natural Chinook salmon. In 2000, the program began capturing returning hatchery fish at Winchester Creek. According to ODFW, in order to maintain the genetic composition/diversity of the broodstock, naturally produced fall Chinook salmon will be incorporated into broodstock per ODFW's Native Fish Conservation Policy guidelines for naturally produced fish stock status. Currently, the proposed number or proportion of natural fish incorporation into broodstock is at least 10%. Until 2000, 100% of the Chinook salmon used for this program were naturally produced. The program now uses at least 10% naturally produced Chinook salmon in its broodstock. Hatchery broodstock are collected during September and October in the lower estuary area, while naturally produced brood are collected from October to November higher upstream.

Coos River fall run (Bandon Fish Hatchery Stock 37)

The presmolt release program began in 1982; the smolt program began in 1983 and discontinued in 2006. The presmolt program has been primarily composed of fish that were unmarked (formerly 7–8% marked); consequently, the ability to document ocean and in-river contributions was not possible with most of the release groups. The initial Coos Hatchery Chinook salmon program began in 1900 and was operated until 1958. During that period, native stocks were mostly utilized early on, but later, out-of-basin stocks were used. Another era in the Coos Chinook salmon hatchery program began with the 1982 brood year and the release of presmolts and unfed fry in the spring of 1983. A hatchery smolt program using Coos River basin broodstock began in brood year (BY) 1983. Approximately 92,000 smolts were released each year from 1984 to 2005. Morgan Creek and Noble Creek facilities were the only two places where smolts were released. Presmolt Chinook salmon have been

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[2] https://www.dfw.state.or.us/fish/HGMP/docs/2016/Umpqua_River_Spring_Chinook_Salmon_HGMP_8-23-16_to_NMFS.pdf

released from multiple locations in the basin. Nearly all of these releases have been in or near tidewater. During the 1980s, private aquaculture facilities released both spring and fall Chinook salmon from primarily out-of-basin stocks, including some 23 million fall-run Chinook salmon from Anadromous, Inc., and Oregon Aqua Foods (Myers et al. 1998). Following the STEP Propagation Project[3] Review in 2005–06, the Coos River fall Chinook salmon program was shifted to strictly presmolt releases, with elimination of the smolt and unfed fry releases.

Coquille River fall run (Stock 44)

Prior to the present hatchery program, there were numerous releases of non-native fish into the Coquille River, primarily from the Coos River, Bonneville (Lower Columbia River), Chetco, and Elk River hatcheries (Myers et al. 1998). The fall Chinook salmon hatchery smolt program using Coquille River basin broodstock began in brood year 1983. Presmolt releases began in 1982, and unfed fry releases began in 1981. Releases of out-of-basin stocks occurred earlier. Approximately 100,000 smolts were released each year since 1983, with the exception of 1991 and 1994, when 54,000 and 61,000 fall Chinook salmon were released, respectively. Prior to 1991, smolts were released at various locations, including sites much higher in the basin. Presently, smolts have been released in the lower portion of the estuary in order to improve survival rates, decrease encounters between outmigrating smolts and anglers, increase residence time of returning adults in areas with an intensive Chinook salmon fishery, and minimize straying of artificially propagated fish into wild fish spawning areas. Around 2006, when the coho salmon hatchery program was eliminated for the Coquille River basin, the equivalent poundage of production was shifted to a 54,600 Chinook salmon smolt acclimation/release for Hall Creek, near Coquille, Oregon. In 2014, that acclimation/release was moved downriver and combined with the lower Ferry Creek release, as a measure of the Coastal Multi-species Conservation and Management Plan (CMP; ODFW 2014a).

Rogue River

Spring run (Cole Rivers Hatchery)

The current program started in 1972; however, there has been a hatchery program in the Rogue River basin since 1877 and on the upper Rogue River since 1890, with tens of millions of juveniles released prior to 1972. The current broodstock originated from wild fish entering the collection pond at Cole Rivers Hatchery. Spring Chinook salmon production at Cole Rivers Hatchery began in 1972. With the exception of age at maturity, hatchery fish currently exhibit life-history characteristics similar to those exhibited by naturally produced spring Chinook salmon before the construction and operation of William Jess Dam and Lost Creek Reservoir. The life history of naturally produced fish has changed to a later migration and spawn timing post-dam construction (ODFW 2007a).

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[3] https://www.dfw.state.or.us/fish/HGMP/docs/2017/Coos_River_Fall_Chinook_Salmon_HGMP_to_NMFS_9-20-17.pdf

Fall run (Indian Creek)

The propagation program of Indian Creek fall-run Chinook salmon began in 1984. Prior to 1989, hatchery fall Chinook salmon releases consisted of Upper Rogue River stock (Stock 052). Since 1991, all broodstock of both hatchery and natural origin have been collected from the Lower Rogue River (Stock 061).

Chetco River fall run (Stock 96)

Fall Chinook broodstock were first collected in 1968, with the first smolt release in 1969. Collection and spawning of Chetco River fall Chinook salmon was initiated in 1968 and used native Chetco River Chinook salmon broodstock representing historic age and run-timing characteristics inherent to the stock. There were non-native releases of fall-run Chinook salmon from the Elk, Coquille, and unknown hatchery sources during the 1960s and 70s, although the majority of releases appear to be of Chetco River origin (Myers et al. 1998).

Smith River (Rowdy Creek Hatchery)

According the HGMP (Tolowa Dee-ni' Nation 2018), the Rowdy Creek hatchery program has two purposes: to provide fish for harvest and to provide educational opportunities to the local community. The primary purpose of the Chinook salmon program is to provide fish for tribal harvest. The HGMP identifies the program releases as between 50,000 and 150,000 subyearling fall-run Chinook salmon per year. According to the HGMP, the Chinook salmon program is operated as an integrated program.

Discussion of ESU Configuration

The genetic data collected over the past ~20 years generally continue to support the OC and SONCC Chinook salmon ESU boundaries that were drawn during the coastwide status reviews (Myers et al. 1998, BRT 1999). In particular, samples from the OC and SONCC are genetically differentiated into distinct groups, providing evidence in support of both the reproductive isolation and evolutionary legacy prongs of the NMFS ESU definition. There are, however, some exceptions that merit consideration.

Boundary between SONCC and UKTR

The team determined that the current boundary between the SONCC and Upper Klamath. Trinity River (UKTR) ESUs should remain at the confluence of the Trinity and Klamath Rivers. The team acknowledged that a genetic study found that samples from Horse Linto Creek (above the confluence) from a single year were genetically more similar to SONCC than to UKTR. However, the team considered that this small stream could well function as a transition zone between these two ESUs, and might change its genetic structure from time to time depending on the composition of the returns. The team therefore did not consider the available information to be sufficient to change the ESU boundary, although continued collection of data from that area would be of interest.

OC spring Chinook salmon hatchery programs and natural Umpqua River spring Chinook

The majority of spring Chinook returns to the Tillamook and Nestucca River watersheds are from segregated hatchery programs that date from the early 20th century. These programs have a history of releases originating from out-of-basin stocks, including from the Rogue and Columbia River systems. Recent genetic analysis (O'Malley, personal communication; Figure 6) indicates that spring Chinook salmon in these basins are genetically distinct from other OC populations, possibly due to this history.

The North Fork Umpqua River spring Chinook hatchery program (Rock Creek) is considered integrated (some natural-origin fish are brought into the broodstock; Table 1), but also has a history of out-of-basin releases from the Rogue and Columbia Rivers. Spring Chinook salmon from this program, and natural-origin spring Chinook salmon in the Umpqua River, also appear to have been genetically influenced by these transfers.

According to the NMFS policy on consideration of hatchery salmon in ESU listings (USOFR 2005), the criteria for determining whether to include hatchery-origin fish in an ESU are:

> Hatchery stocks with a level of genetic divergence relative to the local natural population(s) that is no more than what occurs within the ESU: (a) are considered part of the ESU; (b) will be considered in determining whether an ESU should be listed under the ESA; and (c) will be included in any listing of the ESU.

In considering this policy, the NMFS ESU policy, and the available information, the SRT was uncertain whether hatchery-origin spring Chinook salmon from the Trask and Nestucca Rivers should or should not be included in the OC Chinook salmon ESU. Fish from these long-established hatchery programs are genetically distinct from most natural-origin fish in these basins, and appear likely to have been highly influenced by a combination of documented out-of-basin introductions and a long history of using only hatchery-origin fish for broodstock. These factors suggest that perhaps the hatchery fish produced by these programs are no longer representative of spring Chinook salmon that were historically present in these watersheds. On the other hand, the team was concerned that excluding these fish from the OC Chinook salmon ESU might limit potential recovery options using fish from these programs.

The situation on the Umpqua River is also uncertain, in that both hatchery- and natural-origin spring (but not fall) Chinook salmon are genetically different from other OC populations. In particular, the Umpqua River spring run appears to be genetically similar to the SONCC (spring and fall runs). The Umpqua River spring-run Chinook salmon also are similar to SONCC Chinook in their ocean distribution patterns and age structure. The team considered that historical releases of out-of-basin spring Chinook salmon from the Rogue and Columbia River basins are a likely explanation for this pattern, but also considered the possibility that natural straying of spring Chinook salmon from the Rogue River into the Umpqua River might sometimes occur, or that there are older evolutionary connections between spring Chinook salmon in the Rogue and Umpqua Rivers.

While acknowledging this uncertainty, the team tentatively concluded that both natural- and hatchery-origin spring Chinook salmon in the Umpqua River are part of the OC Chinook salmon ESU. This conclusion was based on the integrated nature of the Rock Creek hatchery, and the continuous recorded presence of natural-origin spring Chinook salmon returning to the Umpqua River since the early 1900s.

The SRT concluded that the Salmon, Trask, Elk, Chetco, Umpqua, Coos, and Coquille River fall-run stocks are part of the OC Chinook salmon ESU, and that the Rogue River spring- and fall-run stocks and the Smith River fall-run stock are part of the SONCC Chinook salmon ESU, based on their local origin and the integrated nature of their broodstocks.

Summary of Historical Demographic Information

Run-Timing Diversity

The documentation of the historical presence of salmon populations within an ESU is relevant to the evaluation of their current viability for a number of reasons. From a diversity perspective, populations or life-history types may have occupied a unique temporal, ecological, and/or geographic niche. This heterogeneity buffers the ESU against short-and long-term changes in climate as well as catastrophic events. Understanding the diversity that maintained historical persistence provides some insight into the ability of an ESU to persist into the future.

All watersheds reviewed in this report support fall runs of Chinook salmon, which typically enter rivers with the onset of fall rains, usually in September or October and continuing into December or January. But many watersheds also support spring- or summer-run life-history types (collectively, "early-run"), and the historical and current status of these alternative life-history types within the OC and SONCC Chinook salmon ESUs is one of the focal points of the petition. In the historical literature, definitions of what constituted a spring-or early-run are elusive, as Chinook salmon in these ESUs express a continuum of phenotypes with respect to time of return from the ocean, upstream migration, and spawning, and the temporal patterns of each run type may differ among watersheds (Nicholas and Hankin 1989). In watersheds draining the Cascade Range (i.e., the Umpqua and Rogue Rivers), spring-run Chinook salmon exhibit patterns typically associated with spring-run Chinook salmon found elsewhere in the Pacific Northwest: individuals enter rivers in immature condition during the period of spring snowmelt, usually April to June, and navigate to upriver holding pools, where they oversummer before continuing on to their spawning grounds in late summer or early fall. However, in a number of coastal basins of Oregon and Northern California with hydrographs that lack a strong snowmelt signature, individuals may also return in late spring, summer, or occasionally both (Nicholas and Hankin 1989). Though these early-run phenotypes may vary to some degree, they share the characteristics that returning fish are "pre-mature" at the time of river entry and must reside for some or all of the summer months in holding pools before they sexually mature and continue on to their spawning habitats. We thus use the term early-run to encompass what are described in various documents as spring- or summer-run Chinook salmon.

For some basins, it has been suggested that the modern presence of spring-run or other early-run life-history types is a consequence of transfers of hatchery fish among basins, some of which began in the late 1800s. We thus undertook a review of available historical information to substantiate the presence of early-returning fish in various watersheds, beginning with the list of populations and life histories (run timings) presented by Nicholas and Hankin (1989) and by the petitioners. We specifically sought, through primary sources, to verify their presence prior to potentially significant hatchery transfers. While the absence of any supporting documentation does not eliminate the possibility that early runs existed in a watershed, it does suggest that at a minimum the population abundance was not large enough to bear notation. The majority of information for our review came from annual reports from the U.S. Fish Commission (USFC; later the U.S. Bureau of Fisheries), and biennial

Table 2. Summary of historical and contemporary occurrence of early-run Chinook salmon in OC and SONCC rivers.

		Historical	Contemporary		
ESU	Population/ River[a]	This report	Nickolas and Hankin (1988)	ODFW (2005)	ODFW (2007, 2014)[b]
OC	Necanicum	no info	no	no	no
	Nehalem	no info	yes	no	yes*
	Tillamook	yes	yes	yes	yes*
	Nestucca	yes	yes	yes	yes*
	Salmon	no info	uncertain	no	no
	Siletz	no info	yes	yes	yes*
	Yaquina	unlikely	yes (rare)	no	no
	Alsea	uncertain	yes	yes	yes*
	Yachats aggregate	no info	no	no	no
	Siuslaw	yes	yes	no (extinct)	no
	Lower Umpqua	yes	yes	no	no
	N Umpqua	yes	yes	yes	yes**
	S Umpqua	yes	yes	yes	yes**
	Coos	unlikely	yes (rare)	no (extinct)	no
	Coquille	unlikely	yes (rare)	yes	yes*
	Flores	no info	no	no	no
	Sixes	no info	no	no	no
	Elk	no info	no	no	no
SONCC	Euchre	no info	no	no	—
	Upper Rogue	yes	yes	yes	yes**
	Lower Rogue	yes	no	no	no
	Hunter	no info	no	no	no
	Pistol	no info	no	no	no
	Chetco	no info	no	no	no
	Winchuck	no info	no	no	no
	Smith	yes	—	—	—
	Blue Cr.	no info	—	—	—

[a] Populations/rivers in bold have strong historical or contemporary evidence for early runs.
[b] ODFW (2014) for OC, ODFW (2007) for SONCC.
Key: — = not included in assessment, * = this report considers the early run to be a variant within a predominantly late-run population, ** = this report considers there to be an independent population consisting primarily of early-run, *no info* = no information on historical run timing could be found, *uncertain* = information on the presence of a historical spring run was uncertain due to either contradictory or confounding information, *unlikely* = vailable information suggests a spring run was unlikely to be present historically.

reports to the Oregon State Legislature, which were variously prepared over the years by the Oregon State Board of Fish Commissioners (OSBFC), the State Fish and Game Protector, the Department of Fisheries of the State of Oregon (ODF), and the Master Fish Warden.

In interpreting these reports, it is important to recognize that commercial fishing and canning of salmon had been underway for years prior to establishment of the Oregon State Board of Fish Commissioners. The 1889 review of coastal fisheries provided catch estimates for a number of basins, with estimates in the tens of thousands of salmon in each basin, although there was often no distinction made between species—in particular between coho and Chinook salmon (OSBFC 1889). The report notes that there were spring runs of Chinook salmon on the Rogue River and the Umpqua River, although the latter was described as "too small to be of any commercial value" (p. 11) The 1889 report indicates that there were active canneries on the Nehalem, Tillamook (2), Nestucca, Yaquina (3), Alsea (2), Siuslaw (3), Umpqua (1), Coquille (2), and Rogue Rivers. Overharvest was clearly a concern in both the Columbia River and coastal watersheds before the turn of the 20th century (gill nets were often noted as completely spanning smaller rivers), and was a primary reason that many of the hatchery programs were initiated. It is unclear what role pre-1887–88 fishing may have played on the status and composition of natural populations, including any early-run components.

The construction of hatcheries along the Oregon Coast in the early 1900s provided much detailed information on the collection and spawning of salmon in a number of basins. Again, it is important to recognize that the Oregon Fish Commission documents were written from a very fishery-centric perspective. The Commissioners and Master Fish Wardens were champions for the fishing industry, and from the earliest days advocated for locating hatcheries throughout the state for the purpose of increasing the harvest of fish at established canneries. Consequently, statements regarding whether or not a particular watershed had early-run Chinook salmon might be better viewed as statements about whether those watersheds had sufficient numbers of early-run fish to support a commercial fishery.

Hatchery adult and egg collection records are also potentially biased in that the timing of the trap installation for broodstock collection determined the reported run and spawn timing of the Chinook salmon collected. A number of notations in the Oregon Department of Fisheries reports show that adults had already passed the location of the hatchery racks a month or two prior to the racks being installed. Alternatively, there is substantial documentation for large abundances of fall-run Chinook salmon in nearly all rivers. Although there is seldom a distinction between run times, nearly all of the cannery pack in the Oregon Coast Chinook salmon ESU in the late 1800s and early 1900s came from returning fall-run Chinook salmon (Table 2).

With those caveats, below we review salient primary literature related to the occurrence of different life-history types in coastal watersheds of the OC and SONCC Chinook salmon ESUs. The review is not exhaustive, but we believe it reflects the available evidence regarding early-run Chinook salmon in each of these ESUs. ODFW has also summarized information on contemporary patterns of run-timing variation for OC and SONCC Chinook salmon (Nicholas and Hankin 1988, ODFW 2005a, 2007b, 2014a). An overall summary of both historical and contemporary information is provided in Table 2.

OC Chinook salmon ESU

Nehalem River

We were unable to find any early descriptions of salmon populations in the Nehalem River. Construction of a hatchery in the watershed did not begin until 1920. The first hatchery was located on the Salmonberry River, a large tributary approximately 25 miles above Nehalem Bay. Egg takes were relatively small and were stated to be fall-run fish.

Additionally, 579,300 spring-run fingerlings were released into the basin (most likely from the Clackamas River) in 1920, and an additional 969,625 spring-run fingerlings from the Columbia River were released in 1922 (Wallis 1961a). Spring-run Chinook salmon eggs were not taken locally until 1925; these may have been the result of the aforementioned releases of Columbia River basin stocks. In 1926, the hatchery was moved to Foley Creek, which is located approximately 9 miles above the bay, in habitat more suited to fall-run Chinook salmon. However, spring-run fish from the Trask, North Santiam, McKenzie, Bonneville, and Klaskanine hatcheries were introduced on multiple occasions between 1928 and 1944 (Wallis 1961a; see the Excel file of supplemental tables [S-Tables]).

Tillamook River basin (Wilson River/Trask River)

Regarding the Tillamook River basin, the Master Warden noted in 1901, "Salmon appear in this bay in limited numbers as early as July, and begin to ascend the river in August, but the main run does not go up the river until after the first heavy rains in September" (ODF 1903, p. 25), suggesting that while the population was dominated by late-run fish, some early-run fish did occur (ODF 1901). Collection of Chinook salmon eggs took place in the Wilson River in 1902 and 1903, and although they are not identified as early- or late-run fish, the timing of egg collection (beginning as early as 11 September) suggests the possibility that some fish were early-run. A collection of 2.5 million eggs in 1907 from a new Trask River facility was described as including "both spring and fall chinook eggs" (Wallis 1963a, pp. 50–51), which predates any known planting of spring-run fish from outside the basin, though there was a small release of fry (<20,000 fry) from an unknown source for which the run type is not identified (S-Tables).

A review of the Tillamook Bay spring Chinook salmon populations (Hodges and Gharrett 1949) reported that, "Some of the early settlers and natives maintain that the spring chinook [sic] salmon were introduced in the early 1900s. From reports of others it appears that spring chinook were observed in these rivers at least as early as the 1890s" (p. 12). Naturally spawning spring-run Chinook salmon were observed in the Wilson and Trask Rivers, with estimated abundances in the low hundreds. Further, they report that in 1923 the commercial catch of spring Chinook salmon was nearly 40,000 pounds, reached approximately 170,000 pounds in 1931, and then subsequently dwindled. Finally, they conclude:

> The short rivers of the Coastal Range cannot produce the large numbers of spring chinook salmon which are found in the more favorable habitat of the large rivers having their headwaters in the Cascade Range. However, it is evident from the past statistics of the commercial fishery that these rivers are capable of producing runs many times the size of those of recent years. (Hodges and Gharrett 1949, p. 16)

It appears that this conclusion could apply to a number of rivers in the Oregon Coast Chinook salmon ESU.

Nestucca River

Prior to the establishment of a hatchery in the Nestucca River basin in 1924, there is little documentation of species or run timing in the river. In each of the first two years of hatchery operation, several million eggs were reportedly collected from spring-run Chinook salmon (OFC 1925 and subsequent biennial reports; S-Tables). Prior to this time, no releases of spring-run Chinook salmon into the basin were documented. Assuming an average fecundity of 4,000–5,000 eggs/female and a 1:1 sex ratio, the available evidence suggests that a natural run of at least several hundred to a few thousand early-run Chinook salmon existed in the Nestucca River.

Salmon River

There is little information on the historical occurrence of early-run Chinook salmon in the Salmon River. Reports indicate that spring-run fingerlings were transferred from the Nehalem and Trask Rivers in the mid-to-late 1930s (OFC 1937, Wallis 1963a), but we found no evidence of their occurrence prior to those introductions.

Siletz River

We found very little information on the historical presence of spring-run Chinook salmon in the Siletz River. A hatchery was established in the Siletz River in 1937, but primarily collected coho salmon and some fall-run Chinook salmon (Wallis 1963b). There were limited transfers of spring-run Chinook salmon from other hatcheries within the OC Chinook salmon ESU from the mid-1920s to the mid-1930s, prior to the establishment of the hatchery (Wallis 1961a, 1963a, 1963c; S-Tables). Thus, the source of the present-day spring run in the Siletz River, whether native or introduced, cannot be determined based on this information alone. However, the genetic similarity between contemporary spring- and fall-run Chinook salmon in the Siletz suggests the spring run are likely of local origin (Figure 6).

Yaquina River

Hatchery operations in the Yaquina River basin began on Big Elk Creek (three miles above confluence with the Yaquina River) in late July 1902, and egg take began in early October of that year (ODF 1903). A new hatchery building was constructed the next year and remained open until 1912. During its first 11 years of operation, 11.45 million eggs were taken (ODF 1903 and subsequent biennial reports; S-Tables); these are presumed to have been fall-run Chinook salmon, since egg take took place almost exclusively in October to December (a few eggs were taken in late September in a single year). During that interval, there was one reported introduction of spring-run Chinook salmon from the Umpqua River (500,000 eggs in BY 1910). Additionally, the facility received a shipment of 3.06 million Chinook salmon eggs from the U.S. Bureau of Fisheries hatchery on the Clackamas River in BY 1903 (ODF 1905); life-history type is not indicated, but it is possible it included spring-run fish. Although, depending on the timing and location of the hatchery racks, it is possible that returning spring-run adults were present but not intercepted, the absence of any mention makes the presence of a spring run unlikely. Relatively small numbers of spring-run Chinook salmon from the Trask and Alsea River hatcheries were transferred to the Yaquina River in the mid-1930s (Wallis 1963a, 1963c).

Alsea River

The occurrence of natural-origin early-run Chinook salmon in the Alsea River seems ambiguous. In 1902, prior to any recorded introductions of spring-run Chinook salmon, attempts to collect adults in the upper Alsea River produced females as early as 15 September, which, given that distance from the ocean (~40 miles), suggests the possibility of early-run fish. Fairly robust spring runs were observed between 1922 and 1928, despite only a single recorded introduction of spring-run fish (Umpqua River origin) in 1910 (Wallis 1963c; S-Tables). Collectively, these observations indicate that early-run Chinook salmon likely occurred naturally in the basin. However, the lack of continued take of spring-run eggs after substantial introductions from the Willamette and Columbia Rivers from 1927 onward is difficult to explain. It would suggest that either these efforts to augment the spring run were unsuccessful or, alternatively, that for practical reasons collecting spring-run fish in the Alsea River was more difficult than acquiring eggs from outside locations.

Siuslaw River

For the Siuslaw River, we found conflicting accounts on the presence of early-run Chinook salmon. An 1895 account indicates that, “This stream has no spring run of salmon. The first fish to enter the river are the chinooks [sic], which arrive about the middle of July; most of the run of this species is in the river by the middle of September, a few also being found up to October 1” (Wilcox 1895, p. 236). In this case, the author has a distinct view of “spring run,” as July entry would be very early for typical coastal fall-run Chinook salmon populations.

A year later, the biennial report notes that, “The run of salmon in the Siuslaw varies greatly from year to year. There is no spring run. The chinook, of which species very few enter this river, commence to run about the first of August” (OFGP 1896, p. 68). However, in the early 1900s, the Master Warden wrote:

> There is an early variety of Chinook salmon that is common to the Siuslaw River, and to stop and get what we could of that variety, the racks were put in much earlier this year than ever before; the one on the mainstem Siuslaw was gotten in July 17 and the one on the Lake Creek fork on July 24. From that time on they were both held intact and the salmon kept below until spawning time. (ODF 1905, p. 171)

This description, which predates any known introductions of spring-run Chinook salmon to the basin, indicates that an early run was likely present, and illustrates the fact that detecting and capturing early-run Chinook salmon required the timely installation of a rack or weir.

Umpqua River

Although initially, early reports suggested that the Rogue River was the only coastal stream with spring-run fish, subsequent sources clearly identified the presence of a spring run of Chinook salmon in the Umpqua River—prior to any hatchery influence. The first biennial report of the OSBFC (1889) noted:

> This river heads in the Calapooia mountains, and receives in the spring months a good supply of snow water; and judging from this fact, it should have a large spring run of Chinook salmon, as they frequent streams that are well supplied with pure snow water, but the supply of this variety is too small to be of any commercial value. (OSBFC 1889, p. 11)

A decade later, the ODF reported:

> The Umpqua is one of our rivers that derives its waters from the western slope of the Cascade Mountains; in consequence of this, it has always been frequented by an early variety of the Chinook salmon; but of late years this species of salmon is almost extinct, but, with a well established hatchery plant some place on its upper waters, there is no reason why this should not be overcome and the stream built up and made as it once was, one of the best coast streams that the state has. (ODF 1901, p. 23)

The implication of this latter report is that spring-run fish were once far more numerous than at the time the hatchery was built in 1900.

Six hundred thousand eggs were shipped in from the Little White Salmon River (most likely fall-run Chinook salmon) in 1900, and an additional 1 million eggs (life-history not specified) were received from the U.S. Bureau of Fisheries station on the Lower Clackamas River in 1902. Otherwise, most eggs were collected locally and fry were released back into North Fork Umpqua River, until 1910 when Umpqua River spring Chinook salmon eggs were delivered to other coastal watersheds including the Yaquina, Alsea, and Siuslaw Rivers.

Coos River

We found little evidence to indicate that early-run Chinook salmon occurred in the Coos River basin. A hatchery was established on the South Coos River in 1900 and reported collecting only fall-run Chinook salmon eggs through 1929. Egg take from spring-run Chinook salmon was reported in 1930–32 (Wallis 1961b); however, this occurred 3–5 years after the introduction of more than 2 million purportedly fall-run Chinook salmon from Bonneville Hatchery in 1927–28 (Wallis 1961b; S-Tables). The timing of these collections, coupled with the lack of subsequent records of egg take from spring-run fish, suggests that perhaps the introductions from Bonneville Hatchery contained some spring-run Chinook salmon.

Coquille River

We found no references to indicate that there were early-run Chinook salmon in the Coquille River. An egg collecting station was established on the Coquille River in 1905. Egg collections were intermittent and, where noted, they appear to have been fall-run Chinook salmon. There were regular and significant exchanges of fall Chinook salmon eggs and fry with the South Coos River Hatchery between 1900 and 1928 (Wallis 1961b; S-Tables).

Summary

We found clear evidence for the occurrence of spring-run Chinook salmon in the Umpqua, Tillamook, Siuslaw, and Nestucca Rivers that predates any known stocking of spring-run Chinook salmon from out-of-basin or out-of-ESU sources. In the case of the Umpqua River, spring-run Chinook salmon were present in numbers sufficient to attract the interest of commercial fisheries. More equivocal evidence also suggests the possible occurrence of early-run Chinook salmon in the Alsea River watershed. For the Siletz River, the information was inadequate for assessing the historical occurrence of early-run Chinook salmon, even though there is a contemporary spring run in this system. Though definitive conclusions cannot be reached for other watersheds, the lack of definitive records—coupled with the general ecological conditions in these watersheds—suggests that, if early-run life-history types were present, they were likely substantially lower in abundance than the fall-run component.

SONCC Chinook salmon ESU

The historical distribution of Chinook salmon populations in the Southern Oregon/Northern California Chinook salmon ESU was initially based on the Oregon populations reported by Nicholas and Hankin (1989) and the California populations reported by Collins (1892) and Snyder (1931).

Rogue River

This ESU was historically dominated by the Rogue River, which supported extensive fisheries for both spring- and fall-run Chinook salmon. The USFC annual report for 1893 stated, “Salmon fishing on the Rogue River is limited by State law; the open season is from April 1 to November 15. By far the largest part of the catch is made during what is known as the spring run, between April 1 and June 30” (Wilcox 1895, p. 232). Data from harvest and fish hatchery collections provide considerable information on abundance, run timing, and spawn timing. The state fish and game protector’s report stated:

> [The Rogue] river has spring and fall runs of chinook [sic], and of the rivers in Oregon is second only in importance to the Columbia river as a salmon stream. Besides [the] Rogue River, there are four other small streams in this county upon which more or less fishing is carried on. They are the Windchuck, Chetco, Sixes, and Elk. (OFGP 1896, p. 71)

Privately owned hatcheries (owned by the Hume Company) operated in both the lower and upper Rogue River as early as the late 1870s. The U.S. Fish Commission assumed operation of the upper Rogue Hatchery in 1897, with the explicit objective of hatching and rearing spring-run Chinook salmon (Ravenel 1899, ODF 1901).

In summary, the presence of early/spring-run and late/fall-run Chinook salmon in the Rogue River is well established, as is the presence of fall-run fish in the other smaller tributaries in the Oregon portion of the SONCC Chinook salmon ESU.

Smith River

There are conflicting reports related to the historical status of Chinook salmon life-history types of the Smith River. Bledsoe (1881) states, “Near its mouth [Smith River] are a number of sloughs, branching out from right and left, and during the fishing season these waters are literally alive with salmon. The fishing season extends from the first of September to the middle of November” (pp. 115–116), which would suggest that the fishery focused on fall-run fish. However, the U.S. Commissioner of Fisheries (Collins 1892, p. 174) reported that, “Salmon is the only object of the fisheries in Del Norte County. There is only a spring run of this species in Smith River,” an assertion repeated in Cobb (1911, 1930), though without additional documentation. This phrase appears in other publications (again without documentation), but the absence of a fall run seems unlikely based on the characteristics of the watershed. A review of commercial catches (1917–28) indicates some July catch; however, the majority of the fish were caught in the fall harvest, August to November (Clark 1930), suggesting that the earlier reports of “only a spring run” were likely in error. As with other basins that were identified as historically having spring-run Chinook salmon, the absence of notable harvest does not exclude the possibility that the spring-run life-history pattern existed at low abundance.

Summary

Evidence from the Rogue River indicates that spring-run Chinook salmon were not only present in the basin, but dominated the commercial catch of Chinook salmon in the early 1890s. Historical records also suggest that spring-run Chinook salmon occurred in the Smith River in California, but accounts as to the relative abundance of spring- and fall-run Chinook are conflicting. Commercial catch records from the early part of the 20th century, coupled with the ecological conditions found in the watersheds, would seem to suggest that fall-run Chinook salmon were numerically dominant.

Historical Abundance

OC Chinook Salmon ESU

Estimating historical abundance presents a number of factors that need to be considered. Meengs and Lackey (2005) used estimated numbers of aboriginal people around 1700 with assumed consumption and harvest rates to estimate the size of the salmon runs (harvest plus escapement) which they were dependent on. The total salmon harvest was then partitioned into coho and Chinook salmon elements. Cannery pack data has commonly been used to estimate abundance (Craig and Hacker 1938, Mullen 1981, Myers et al. 1998; all include variations on the estimate of wastage in canning, wastage pre-canning, harvest rates, and average fish size). Further, some consideration is given to the fact that, by the 1900s, many watersheds had already been subject to 20 or 30 years of intensive harvest and were already degraded by timber harvest activities (including splash dams) and conversion of forest to farmland. Additionally, salted and fresh salmon sales and subsistence harvest are not included in cannery pack-based estimates.

Table 3. Catch (by river) of Chinook salmon, 1909. Expansion to run size was based on a 22-lb average weight and a 50% harvest rate. Data from Cobb (1911).

County	River(s)	Year	Catch (lb)	Expansion
Clatsop	Nehalem River	1909	50,284	4,571
Tillamook	Tillamook Bay	1909	314,810	28,619
	Nestucca River	1909	52,733	4,794
	Siletz River	1909	87,304	7,937
Lincoln	Yaquina River	1909	62,912	5,719
	Alsea River	1909	112,281	10,207
Coos	Coquille River	1909	31,500	2,864
Lane	Siuslaw River	1909	97,304	8,846
Douglas	Umpqua River	1909	62,912	5,719

In order to understand the historical abundance of the OC Chinook salmon ESU, we expanded the peak catch year for each river from the period 1893 to 1917 (Table 3). Prior to 1911, most of the hatcheries released unfed fry, and the survival of these releases was likely very low. In some cases, early hatchery operations effectively mined the adult returns rather than supplementing them, and often eggs and fry were shipped out of the ESU to other areas. Similarly, transfers between hatcheries and from outside of the ESU are thought to have had little positive effect on abundance during this early period. Peak abundance estimated this way was compared to the historical abundance estimate from Myerset al. (1998) and Meengs and Lackey (2005) in Table 4.

Table 4. Harvest-based Chinook salmon abundance estimates for the OC Chinook salmon ESU.

Year(s)	Run size	Source
1895	84,098	This report; Cobb (1911)
1909	79,276	This report; Cobb (1911)
1893–1917	477,190*	This report; Cobb (1911)
1893–1917	225,000*	Myers et al. (1998)
1893–1917	312,000*	Meengs and Lackey (2005)

*Estimated peak run size during this period.

SONCC Chinook Salmon ESU

Harvest totals and estimated abundances are strongly influenced by the Rogue River, although there were considerable catches for the smaller coastal tributaries (Table 5). Reported harvests may include coho salmon. Harvests in smaller tributaries were often consumed locally or shipped to be canned elsewhere; for example, it was noted that fish caught in the Chetco River were often taken to the Smith River for canning.

Table 5. Harvest-based Chinook salmon abundance estimates for the SONCC Chinook salmon ESU.

Year(s)	Run size	Source
1895	109,129	This report; Cobb (1911)
1909	141,807	This report; Cobb (1911)
1893–1917	296,926*	This report; Cobb (1911)
1893–1917	225,000*	Myers et al. (1998)
1893–1917	154,000*	Meengs and Lackey (2005)

*Estimated peak run size during this period.

Current Demographic Risk Analysis

Statistical Methods for Time-Series Analyses

To understand trends in the escapement for Chinook salmon stocks, we followed Ford (2022) in using multivariate dynamic linear models (DLMs) to estimate population-specific trends for the fall- and spring-run populations with sufficient escapement data. The DLMs provide an estimate of the smoothed abundance after accounting for observation and process errors (see Ford [2022] and citations therein for a broader review of DLMs used in salmon time-series analysis). We developed a Bayesian implementation of the models used in the multivariate autoregressive state-space modeling (MARSS) package (Holmes et al. 2012, 2021, 2023) that have been widely applied to understanding trends in salmon populations (Ford 2022). For completeness, we detail the full DLM used in the analysis of Chinook salmon populations, and then summarize how we used model output to describe population trends.

Let Y_{it} represent the observed abundance, and X_{it} be the true abundance of population i in year t. We write the observed abundance as a stochastic function of the true abundance,

$$Y_{it} \sim LogNormal\left(\log\left(X_{it}\right) - \frac{\sigma_R^2}{2}, \sigma_R^2\right) \tag{1}$$

This form assumes that the observed abundances are unbiased relative to the true abundance (for the above distribution has expected value $E[Y_{it}] = X_{it}$), and that the amount of spread above and above and below the true abundance is controlled by the parameter σ_R^2. This is known as the observation equation because it shows how observations are derived from the true, but unknown, abundance. In addition to this observation equation, we need a process model to describe how abundances change through time. We used a log-linear model for the process model and model populations $i = 1,2,\ldots,I$ simultaneously to allow for multiple populations to be correlated in time. Let $\boldsymbol{X}_t$ represent a vector of I populations in year t, $\boldsymbol{\mu}$ be a vector of population-specific growth rates, and $\boldsymbol{\varepsilon}_t$ represent a vector of process variability due to environmental or other stochastic processes. We write the true abundance in year t as a function of the abundance in year $t-1$,

$$\begin{gathered}\log(\boldsymbol{X}_t) = \log(\boldsymbol{X}_{t-1}) + \boldsymbol{\mu} + \boldsymbol{\epsilon}_t \\ \boldsymbol{\epsilon}_t \sim MVN(\mathbf{0}, \mathbf{Q})\end{gathered} \tag{2}$$

Where MVN indicates the multivariate normal distribution centered on mean 0 and covariance matrix $\boldsymbol{Q}$. We impose a relatively simple covariance structure, with $\boldsymbol{Q}$ defined by two parameters, a processes variance parameter σ_Q and correlation among populations, θ, such that the diagonal elements of the covariance matrix are σ_Q^2 and off diagonal elements are $\theta\sigma_Q^2$. This parameterization is equivalent to the $\boldsymbol{Q}$ = "equalvarcov" in the *MARSS* package. For example, with a group of three populations, $\boldsymbol{Q}$ would be

$$\boldsymbol{Q} = \begin{bmatrix} \sigma_Q^2 & \theta\sigma_Q^2 & \theta\sigma_Q^2 \\ \theta\sigma_Q^2 & \sigma_Q^2 & \theta\sigma_Q^2 \\ \theta\sigma_Q^2 & \theta\sigma_Q^2 & \sigma_Q^2 \end{bmatrix} \tag{3}$$

This model assumes that there is a single observation variance, σ_R^2, and a single process variance, σ_Q^2, shared among all populations, and that the correlation among all populations is defined by a single parameter, θ.

We used diffuse priors for all parameters and used slightly informative prior parameters for σ_R^2 among different populations to improve model estimation (see Table 6). For Gamma prior distributions, we use the α,β parameterization of the Gamma distribution.

We implemented the above model in the statistical software *Stan* as implemented in the R computing language (Stan Development Team 2022, R Core Team 2023). *Stan* uses a Hamiltonian Markov Chain Monte Carlo (MCMC) algorithm to estimate parameters. For all models, we ran five MCMC chains starting from random starting points, and assessed model convergence using visual diagnostics and $\hat{R}$ metrics (Gelman and Rubin 1992). In general, we used 2,000 burn-in and 2,000 monitored iterations for MCMC.

Table 6. Prior distributions for parameters used in DLMs.

Parameter	Prior distribution	Parameter description
μ_i	*Normal*(0,1)	Trend for population *i*.
σ_R^2	*Gamma*(1,1) or *Gamma*(4.5,3)	Observation variance.
σ_Q^2	*Gamma*(1,1)	Process variance.
θ	*Uniform*(−1,1)	Correlation among populations in process variability.
$\log(X_{i0})$	*Normal*(7,5)	Initial population size on the log scale.

The model provides estimates of the above parameters as well as the abundance in each year, X_{it}. We can use the MCMC samples to estimate the mean and 95% credible intervals for abundance of each population in each year. In addition, we can use MCMC samples to sum across populations and develop estimates of ESU-wide abundance across populations (mean and 95% credible intervals).

OC Chinook Salmon ESU

Current populations and data description

This section provides an overview of demographic data and trends for the OC Chinook salmon ESU. ODFW divides OC Chinook salmon into two Species Management Units (SMUs): a largely fall-run SMU divided into 18 populations, and a spring-run SMU divided into two populations (ODFW 2014a). The fall-run Chinook salmon life-history pattern is numerically dominant in the OC ESU, with populations present in all major rivers between the Nehalem River in the north and Elk River in the south (Figure 1). Early-run (spring- or summer-run) life histories are present in many of the same rivers, including the Nehalem, Tillamook, Nestucca, Siletz, Alsea, and Coquille, where they are considered to be demographically part of the same populations as the fall runs—with the exception of the

Umpqua River, where the spring runs are considered to be separate populations from the fall run (ODFW 2014a). Historically, additional rivers may have also contained a spring-run life-history component. For fall-run SMU populations, annual estimates of total escapement (hatchery and naturally produced fish combined) are available from 1986–2021. With the exception of the Umpqua River (see next section), only limited information is available for the spring-run life history (ODFW 2014a). Separate estimates of natural-origin and hatchery-origin spawners are available from 2014–20 for most rivers, and for 1998–2021 for the Elk and Salmon Rivers. Only combined (hatchery and natural-origin) spawning abundance estimates are available for the Sixes and Floras Rivers.

ODFW recognizes two independent spring-run populations in the OC spring-run Chinook salmon SMU, one each in the north and south forks of the Umpqua River. Annual estimates of natural escapement are available from 1986–2022 (ODFW 2023). In addition to escapement estimates, counts of spring-run Chinook salmon passing Winchester Dam on the North Umpqua River are available from 1946–2022 and provide a longer-term view of population trends. Winchester Dam is located approximately four river miles upstream of the confluence with the South Umpqua River, and forty river miles downstream of Rock Creek Hatchery (Figure 1). These counts include both hatchery- and natural-origin individuals. Because fisheries occur upstream of Winchester Dam, counts at the dam are an imperfect proxy for escapement. In practice, however, counts of natural-origin Chinook salmon at the dam and natural escapement are nearly perfectly correlated for 1986–2021 (Pearson product–moment correlation; $\rho > 0.95$), suggesting Winchester Dam counts are likely a good proxy for trends in natural escapement. Estimates of hatchery contributions to natural spawning escapement in the North Umpqua River are available from 1984–2020.

Trend analyses

For all component populations, we calculated smoothed time series of spawner abundances using the methods described in Statistical Methods for Time-Series Analyses, geometric-mean abundances for each five-year window, and population trends over 15-year windows of the time series. In addition, we summed the component population abundances to provide a time series of aggregate abundance across the individual run types (fall and spring runs), as well as all Chinook salmon spawners combined. Due to data differences between the OC fall- and spring-run SMUs, we construct slightly different DLMs for fall- and spring-run Chinook salmon.

For fall-run populations, we constructed a DLM using total escapement data for each river (Figure 12). We used a single observation variance (log-scale) for all populations and a single process variance and single covariance for the process covariance (equivalent to the *MARSS* options R = “diagonal and equal” and Q = “equalvarcov,” respectively). This model includes data from 14 component populations. Information on the fraction of natural-origin spawners is available for 12 of the 14 populations (no data on hatchery contributions were available from Floras Creek or the Sixes River) from 2014–21 (Figure 13). For the two populations that are indicator stocks for the Pacific Salmon Commission’s (PSC) Chinook salmon model (Salmon and Elk Rivers), time series of the fraction of wild spawners extend further back in time, to 1998–2021 (CTC 2022c; Figure 13). Due to substantially greater hatchery production in the Salmon and Elk River systems, the proportion of natural

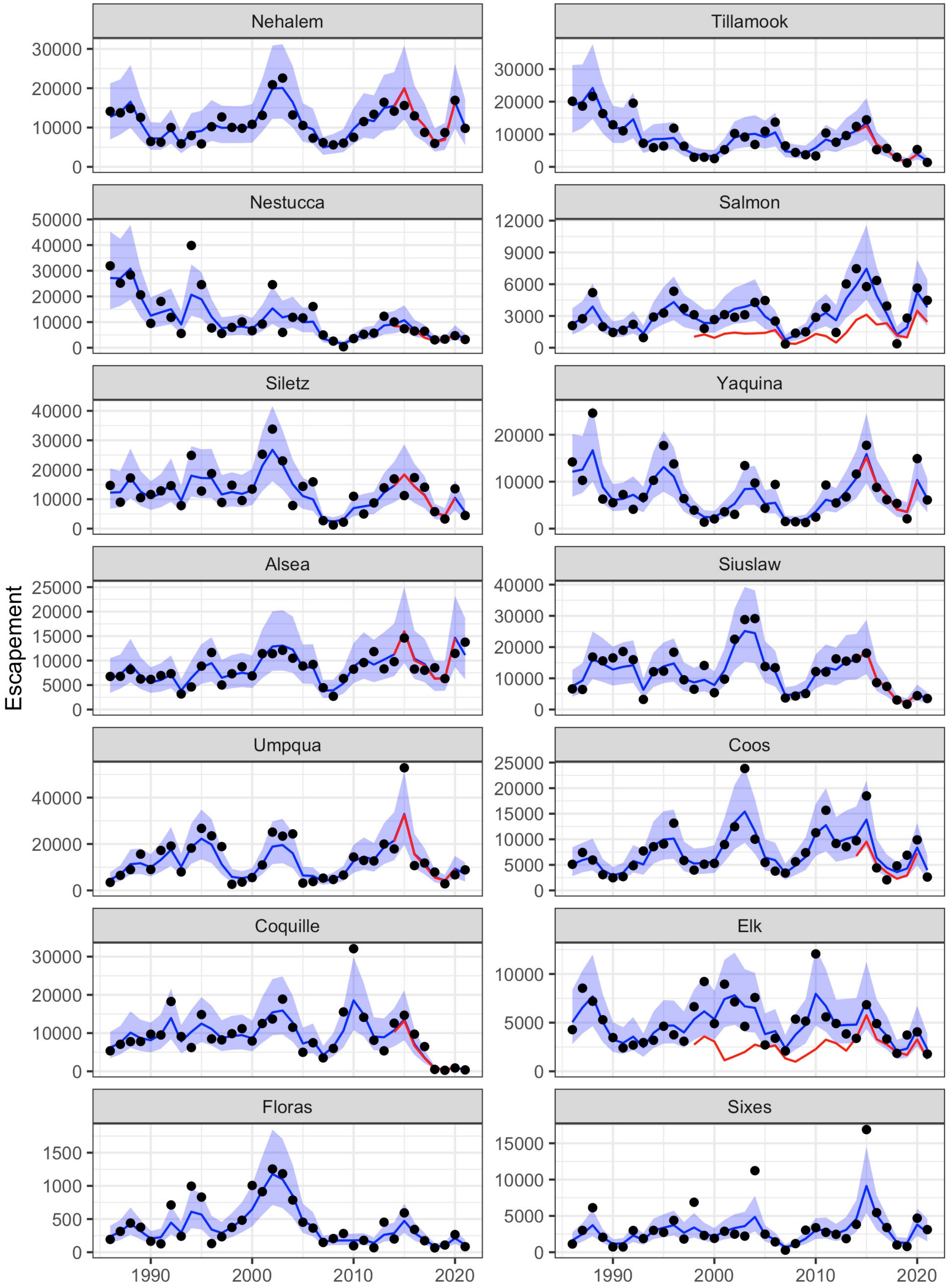

Figure 12. Total escapement (natural + hatchery) for fall-run populations in the SONCC ESU. Points show observations, blue line and shaded area shows model predictions of abundance and 95% CI. Natural-origin escapement estimates are shown in red for years with data on natural origin.

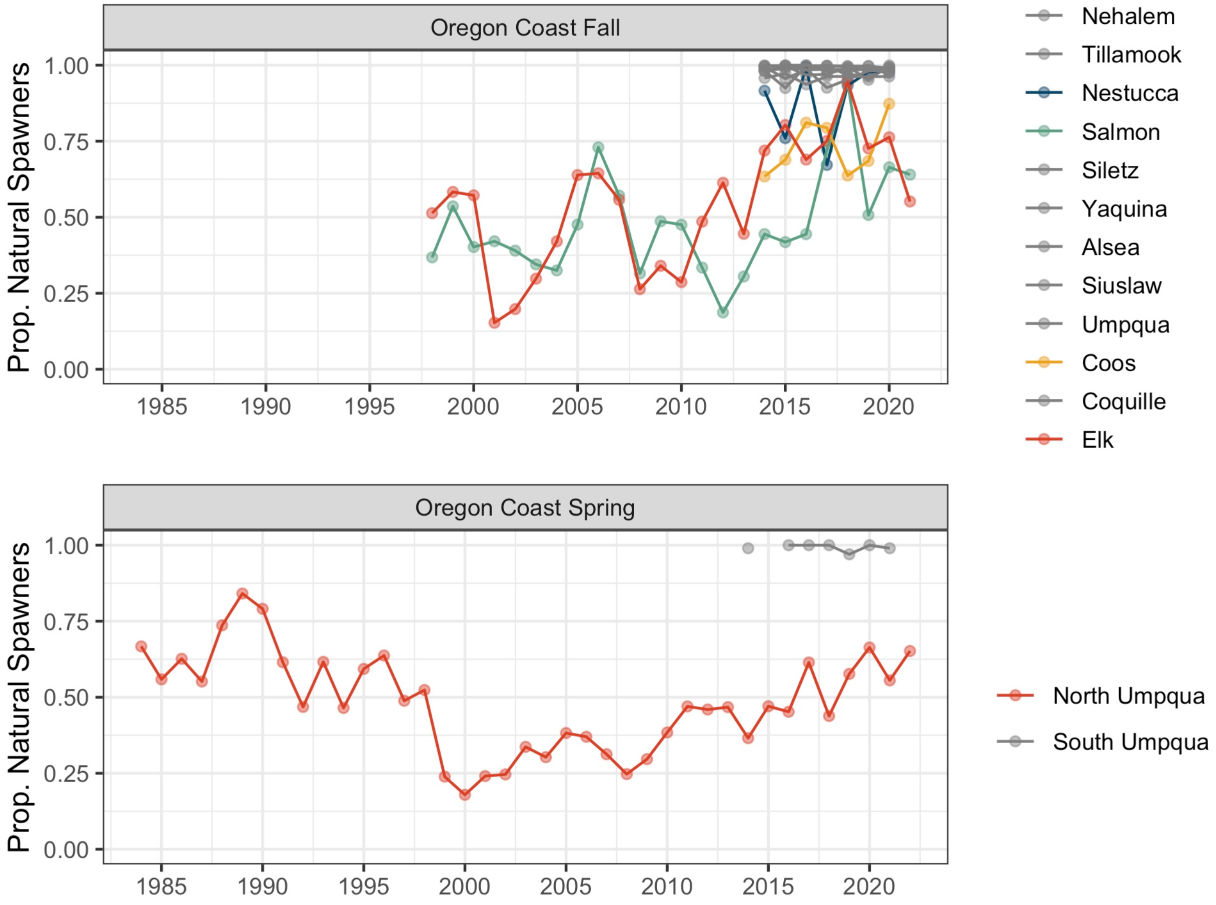

Figure 13. Proportion of natural-origin spawners for all populations in the OC Chinook salmon ESU, plotted by run type. There are no estimates for Floras Creek or the Sixes River.

spawners will not be representative of other populations between 1998 and 2013. We multiply the smoothed estimate of total returns by the proportion of natural spawners to provide a smoothed estimate of natural-origin spawner abundance for 1998–2021 (Salmon and Elk Rivers) or 2014–21 (remaining rivers other than Floras and Sixes; Figure 12).

For spring-run populations, we constructed a DLM based on two natural-origin escapement time-series (Figure 14) and fish counts at Winchester Dam (Figure 15). We use the same model structure as the fall-run stocks (equivalent to the *MARSS* options *R* = “diagonal and equal” and *Q* = “equalvarcov”). Proportion of natural-origin spawners is available for the North Umpqua River from 1984–2022, but only available from 2014–2020 for the South Umpqua River (Figure 13). Counts of both natural- and hatchery-origin Chinook salmon are available at Winchester Dam but, due to fisheries and segregation by fish origin above the dam, the proportion of natural-origin fish passing the dam will not be equivalent to the proportions present on the spawning grounds.

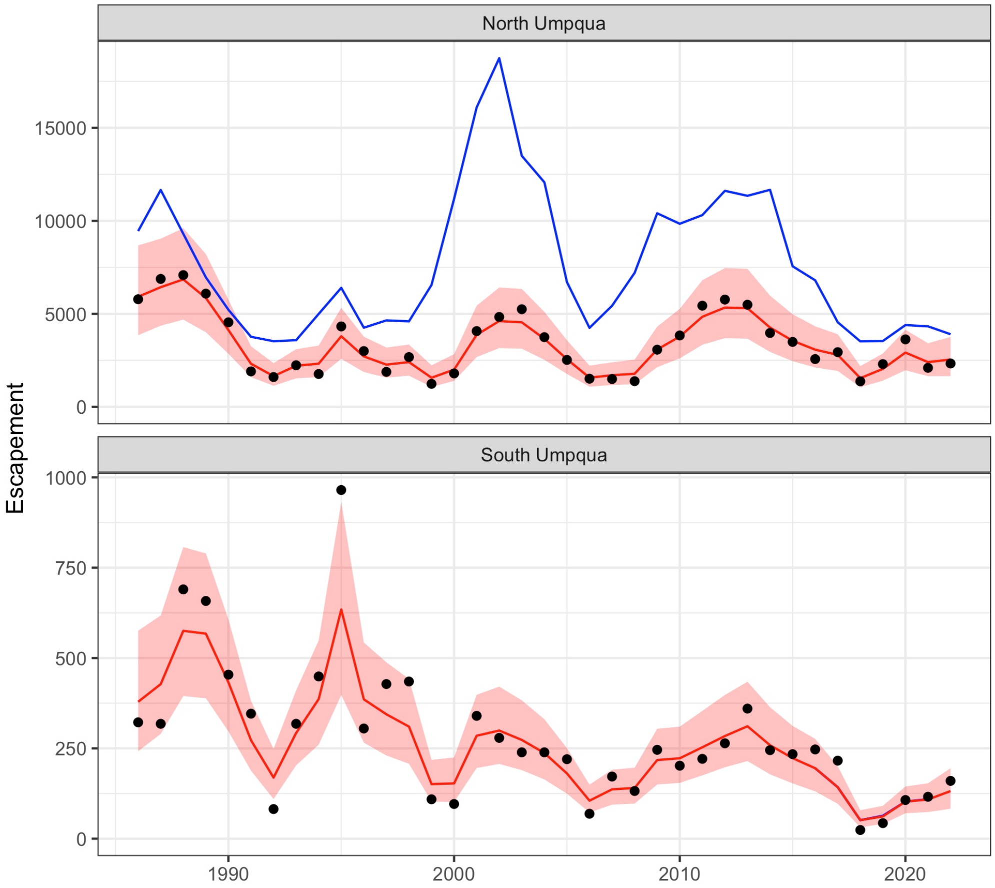

Figure 14. Natural-origin escapement time series for spring-run stocks in the OC Chinook salmon ESU. Points show observations, red line and shaded area show model predictions of abundance and 95% CI. Total escapement estimates are shown in blue.

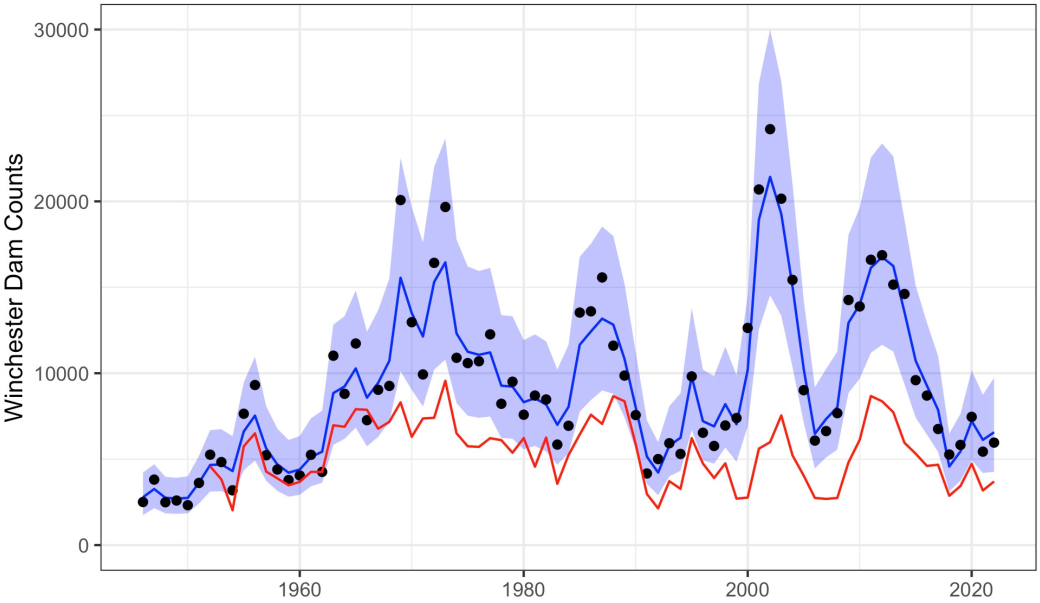

Figure 15. Counts of spring-run stocks passing Winchester Dam on the North Umpqua River. Points show observations and lines indicate smoothed estimates from the *MARSS* model (blue indicates total abundance, red indicates natural abundance).

We calculated 15-year trends derived from linear regressions of year against log-transformed escapement estimates from the DLM against years (Figure 16, Tables 7–9). We calculated geometric means for each five-year period for each population using output from the MARSS model (Tables 10–12).

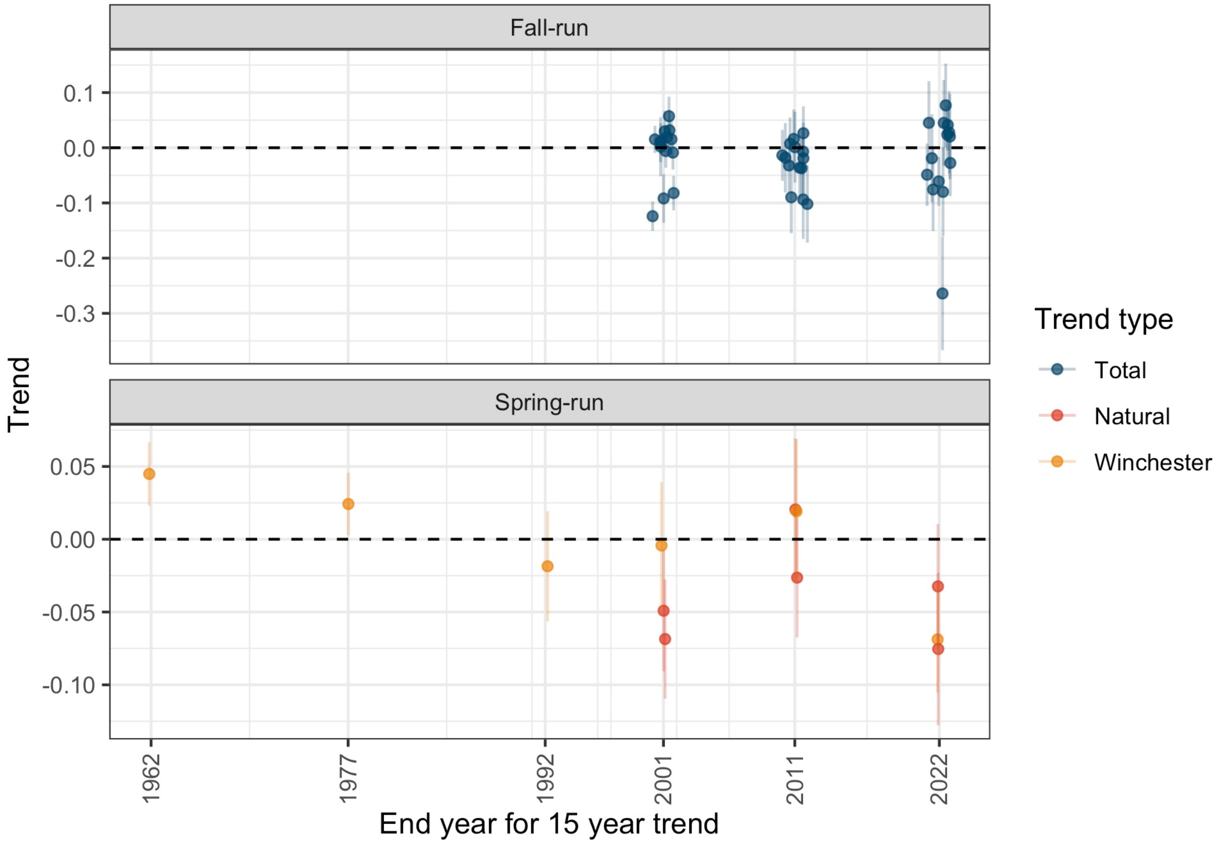

Figure 16. 15-year escapement trends estimated for fall-run stocks (total escapement) and spring-run stocks (natural-origin escapement to the North and South Umpqua Rivers and total passage at Winchester Dam). Points show estimated trends through time and 95% CI for individual stocks (points are located at the end of each 15-year period). Points have been slightly jittered to reduce overlap. Data for fall-run populations end in 2021.

Table 7. 15-year trends (slope) in log total spawner abundance for fall-run stocks, computed from a linear regression applied to the smoothed spawner log abundance estimate versus year. In parentheses are the upper and lower 95% CIs. Only populations with at least four spawner estimates and with at least two data points (observations, not estimates) in the first five years and last five years of the 15-year ranges are shown.

Population	**1986–2001**	**1997–2011**	**2007–21**
Nehalem River	−0.01(−0.04,0.02)	−0.03(−0.08,0.02)	0.02(−0.03,0.08)
Tillamook River	−0.12(−0.15,−0.10)	0.03(−0.02,0.07)	−0.08(−0.15,0.00)
Nestucca River	−0.08(−0.11,−0.05)	−0.09(−0.15,−0.02)	0.03(−0.05,0.10)
Salmon River	0.02(−0.02,0.05)	−0.04(−0.09,0.02)	0.05(−0.03,0.12)
Siletz River	0.01(−0.01,0.04)	−0.10(−0.17,−0.03)	0.05(−0.03,0.12)
Yaquina River	−0.09(−0.14,−0.05)	−0.02(−0.08,0.05)	0.08(0.00,0.15)
Alsea River	0.02(−0.01,0.04)	−0.01(−0.06,0.03)	0.04(−0.01,0.09)
Siuslaw River	−0.01(−0.04,0.02)	−0.02(−0.08,0.04)	−0.08(−0.16,0.00)
Umpqua River	0.00(−0.05,0.06)	0.00(−0.06,0.07)	−0.02(−0.10,0.06)
Coos River	0.03(0.00,0.07)	0.02(−0.04,0.07)	−0.05(−0.11,0.01)
Coquille River	0.02(0.00,0.04)	0.01(−0.04,0.05)	−0.26(−0.37,−0.16)
Floras Creek	0.06(0.02,0.09)	−0.09(−0.17,−0.02)	−0.03(−0.09,0.03)
Sixes River	0.03(−0.01,0.07)	−0.04(−0.09,0.02)	0.02(−0.06,0.10)
Elk River	0.01(−0.03,0.04)	−0.01(−0.05,0.03)	−0.06(−0.11,−0.02)

Table 8. 15-year trends (slope) in log natural-origin spawner abundance for spring-run stocks, computed from a linear regression applied to the smoothed natural spawner log abundance estimate versus year. In parentheses are the upper and lower 95% CIs. Only populations with at least four spawner estimates and with at least two data points (actual observations) in the first five years and last five years of the 15-year ranges are shown.

Population	**1986–2001**	**1997–2011**	**2008–22**
North Umpqua River	−0.07(−0.11,−0.03)	0.02(−0.03,0.07)	−0.03(−0.08,0.01)
South Umpqua River	−0.05(−0.09,−0.01)	−0.03(−0.07,0.01)	−0.08(−0.13,−0.02)

Table 9. 15-year trends (slope) in log total spawner abundance passing Winchester Dam for spring-run stocks, computed from a linear regression applied to the smoothed spawner log abundance estimate versus year. In parentheses are the upper and lower 95% CIs. Only populations with at least four spawner estimates and with at least two data points (actual observations) in the first five years and last five years of the 15-year ranges are shown.

Population	**1946–62**	**1963–77**	**1978–92**	**1986–2001**	**1997–2011**	**2008–22**
Winchester Dam	0.05(0.02,0.07)	0.02(0.00,0.05)	−0.02(−0.06,0.02)	0.00(−0.05,0.04)	0.02(−0.03,0.07)	−0.07(−0.10,−0.03)

Table 10. 5-year geometric mean of populations of Oregon Coast fall-run Chinook salmon. Smoothed wild spawner estimates (smoothed total spawners × fraction wild) are shown. In parentheses, the 5-year geometric mean of smoothed total spawners is shown. An entry with only values in parentheses indicates that no fraction wild estimates were available for that population. Geometric mean was computed as the product of counts raised to the power 1/(number of values in band). Note that in rare cases, the natural spawner estimate exceeds the total spawner estimate (e.g., Siletz River 2017–21). This occurs because we only have data on the proportion of natural-origin fish for 2014–20, so the geometric mean abundance for natural-origin and total spawners includes slightly different years (e.g., 2017–20 vs. 2017–21).

Population	1987–91	1992–96	1997–2001	2002–06	2007–11	2012–16	2017–21
Nehalem R.	(10,558)	(8,599)	(10,810)	(14,532)	(7,230)	15,812 (14,760)	9,282 (9,581)
Tillamook R.	(16,302)	(9,219)	(4,238)	(9,702)	(5,341)	9,794 (9,430)	2,965 (2,743)
Nestucca R.	(19,482)	(14,558)	(8,334)	(11,840)	(2,966)	7,844 (8,036)	3,592 (3,906)
Salmon R.	(2,342)	(2,674)	1,130 (2,748)	1,437 (3,320)	703 (1,652)	1,649 (4,815)	1,867 (2,739)
Siletz R.	(12,740)	(15,004)	(13,693)	(15,741)	(4,095)	15,624 (13,059)	7,240 (6,953)
Yaquina R.	(9,386)	(9,159)	(3,470)	(6,435)	(2,652)	11,498 (9,365)	5,656 (5,868)
Alsea R.	(6,869)	(6,812)	(7,661)	(10,914)	(5,920)	12,142 (11,167)	8,487 (9,044)
Siuslaw R.	(13,071)	(11,638)	(9,589)	(18,558)	(7,300)	14,322 (14,226)	3,873 (3,774)
Umpqua R.	(10,391)	(17,065)	(7,531)	(11,875)	(7,526)	22,017 (19,396)	6,935 (7,195)
Coos R.	(4,330)	(7,596)	(6,173)	(9,795)	(6,891)	6,925 (9,733)	3,613 (4,670)
Coquille R.	(8,726)	(10,870)	(9,602)	(11,293)	(9,548)	9,716 (9,678)	1,011 (891)
Floras Creek	(288)	(438)	(504)	(726)	(175)	(271)	(130)
Sixes R.	(1,933)	(2,713)	(2,706)	(2,996)	(1,665)	(4,404)	(2,257)
Elk R.	(4,762)	(3,776)	2,421 (5,539)	2,226 (5,568)	1,742 (4,704)	3,325 (5,182)	2,073 (2,813)

Table 11. 5-year geometric mean of populations of OC spring-run Chinook salmon. Smoothed wild spawner estimates (smoothed total spawners × fraction wild) are shown. In parentheses, the 5-year geometric mean of smoothed total spawners is shown. An entry with only values in parentheses indicates that no fraction wild estimates were available for that population. Geometric mean was computed as the product of counts raised to the power 1/(number of values in band).

Population	1986–90	1991–95	1996–2000	2001–05	2006–10	2011–15	2016–20
North Umpqua R.	5,745 (8,196)	2,369 (4,332)	2,158 (5,826)	3,772 (12,703)	2,231 (7,014)	4,605 (10,361)	2,395 (4,422)
South Umpqua R.	471	318	249	252	158	264	98

Table 12. 5-year geometric mean, spring-run Chinook salmon passing Winchester Dam on the north fork of the Umpqua River. Geometric mean was computed as the product of counts raised to the power 1/(number of values in band).

Population	1946–50	1951–55	1956–60	1961–65	1966–70	1971–75	1976–80	1981–85	1986–90	1991–95	1996–2000	2001–05	2006–10	2011–15	2016–20
Winchester Dam	(2,840)	3,772 (4,679)	4,245 (5,165)	5,867 (7,493)	7,247 (11,273)	7,218 (13,357)	5,912 (9,743)	5,094 (8,553)	7,440 (11,278)	3,440 (5,991)	3,663 (7,823)	5,563 (16,432)	3,585 (9,271)	7,076 (14,483)	3,982 (6,658)

Aggregate trends

We combined the escapement estimates for each stock to provide an aggregate time series for the total spawner abundance. The Bayesian DLM provides smoothed estimates of the abundance of each stock in each year (replicate draws from the posterior distribution of abundance in river in each year), and we summed across stocks to arrive at an estimate of abundance across all stocks within the ESU. We summarized the abundance for fall- and spring-run stocks within the ESU (Figures 17 and 18). While the spring-run abundance represents natural-origin spawning escapement, the fall-run estimates are total abundance (natural- and hatchery-origin spawner abundance combined). In the absence of more complete data on the proportion of natural-origin Chinook salmon in each river, creating a time series of only natural-origin fish for fall-run stocks would require making additional assumptions about the proportion of natural-origin spawners in each river. We elected not to pursue that analysis.

Aggregated across populations, both fall- and spring-run OC Chinook salmon are characterized by what appear to be cyclical variations in abundance, ranging from ~50,000 to ~200,000 spawners (fall) and ~2,000 to ~5,000 spawners (spring). Peaks and troughs in abundance appear to occur at similar time points for each run type, with the last peak in abundance occurring around 2012–15 (Figure 17). Spawning abundance in the last few years (2018–22) has been low, similar to previous low cycles in the early and late 1990s and 2006–08.

Trends in the early-returning component of coastal, nominally fall-run OC populations

In addition to spawner abundance data, longer-term data are available in a subset of river systems for the early-run components of stocks monitored within what are otherwise predominantly fall-run OC Chinook salmon populations. In the Tillamook (Wilson and Trask Rivers) and Nestucca River populations, snorkel monitoring of Chinook salmon resting holes has provided an index of early-run abundance since 1965 (ODFW 2023; Figure 19). The amount of survey effort (number of pools surveyed) varies over years in these early-run data. In the Siletz River, counts of early-run Chinook salmon observed in a trap at Siletz Falls provide an index of abundance for the upper portion of the basin (Figure 20). Historical information indicates that early-run Chinook salmon were not present above Siletz Falls prior to the construction of the fish ladder in 1952. The ladder was subsequently replaced with a trap in 1994 to allow the sorting of fish transported above the falls. Also in the Siletz

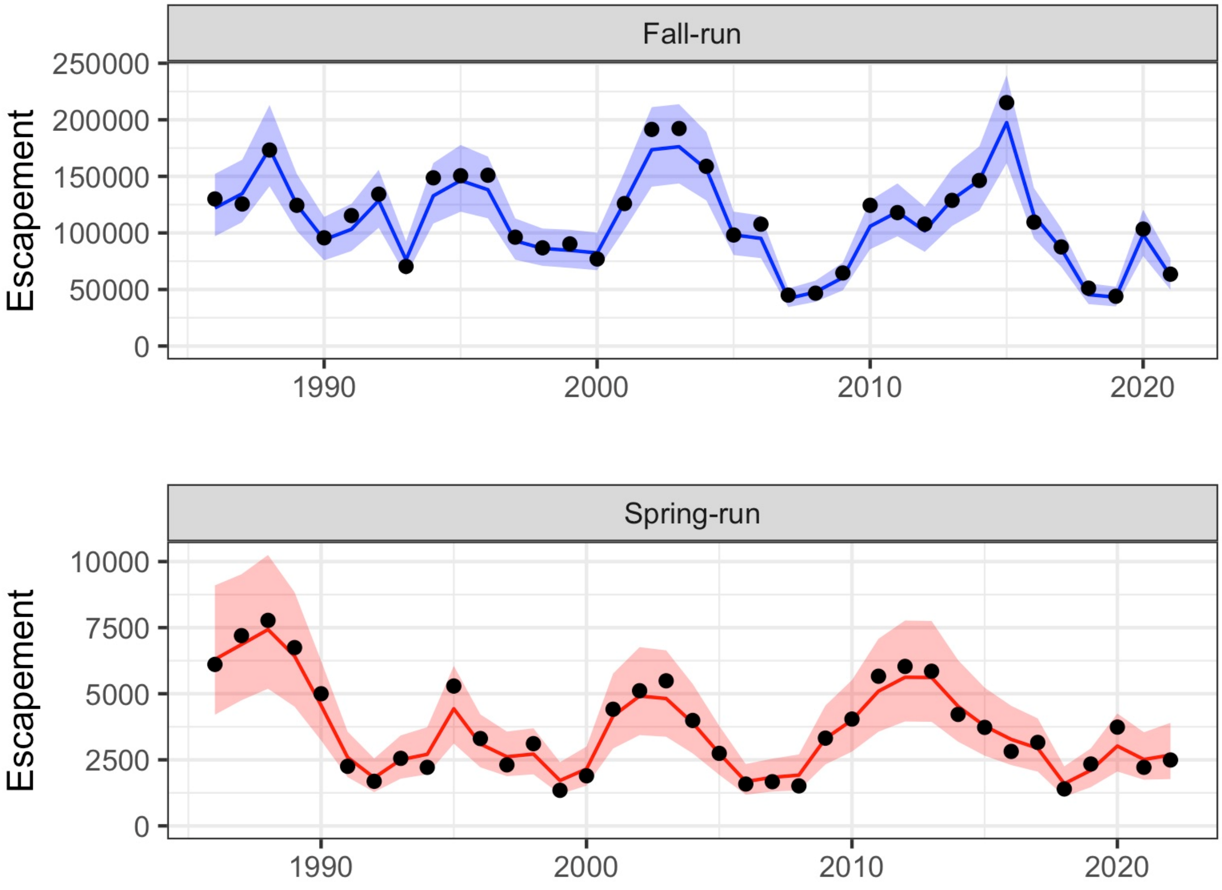

Figure 17. Escapement time series summed across all Oregon coast rivers for fall run (top panel; total escapement, blue) and spring run (bottom panel; natural-origin escapement, red). Points show observations and lines indicate the smoothed estimates from the DLM.

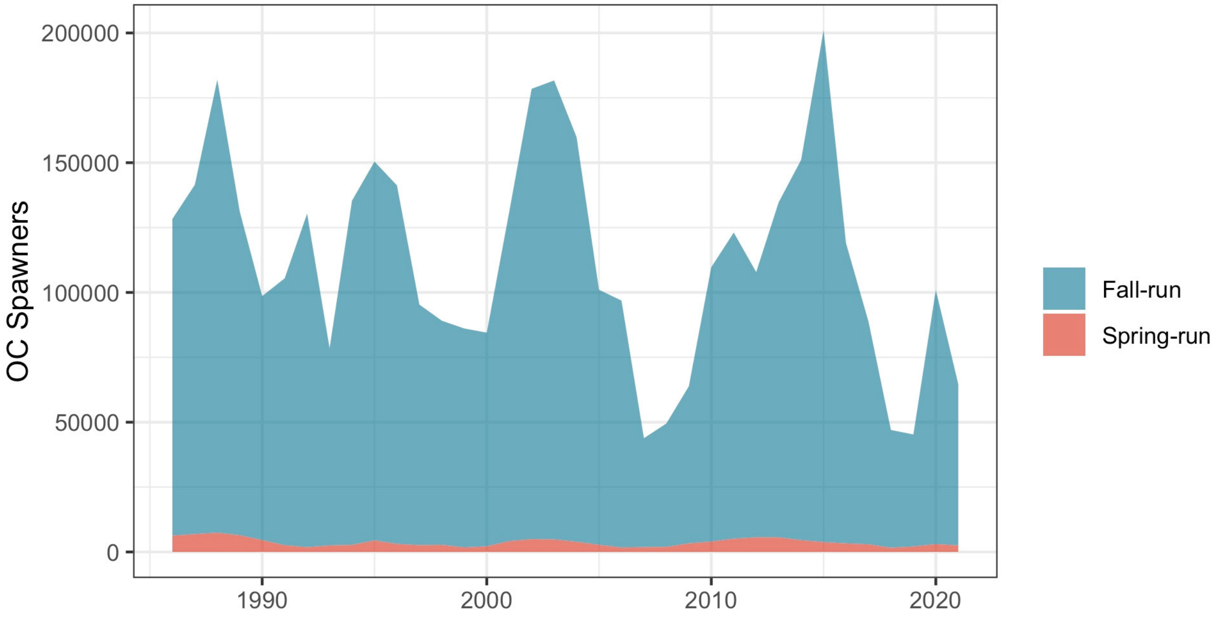

Figure 18. Escapement time series for both the spring and fall runs together. Mean estimated natural-origin spawners for spring-run and the total (hatchery-origin + natural-origin) fall-run spawners are shown.

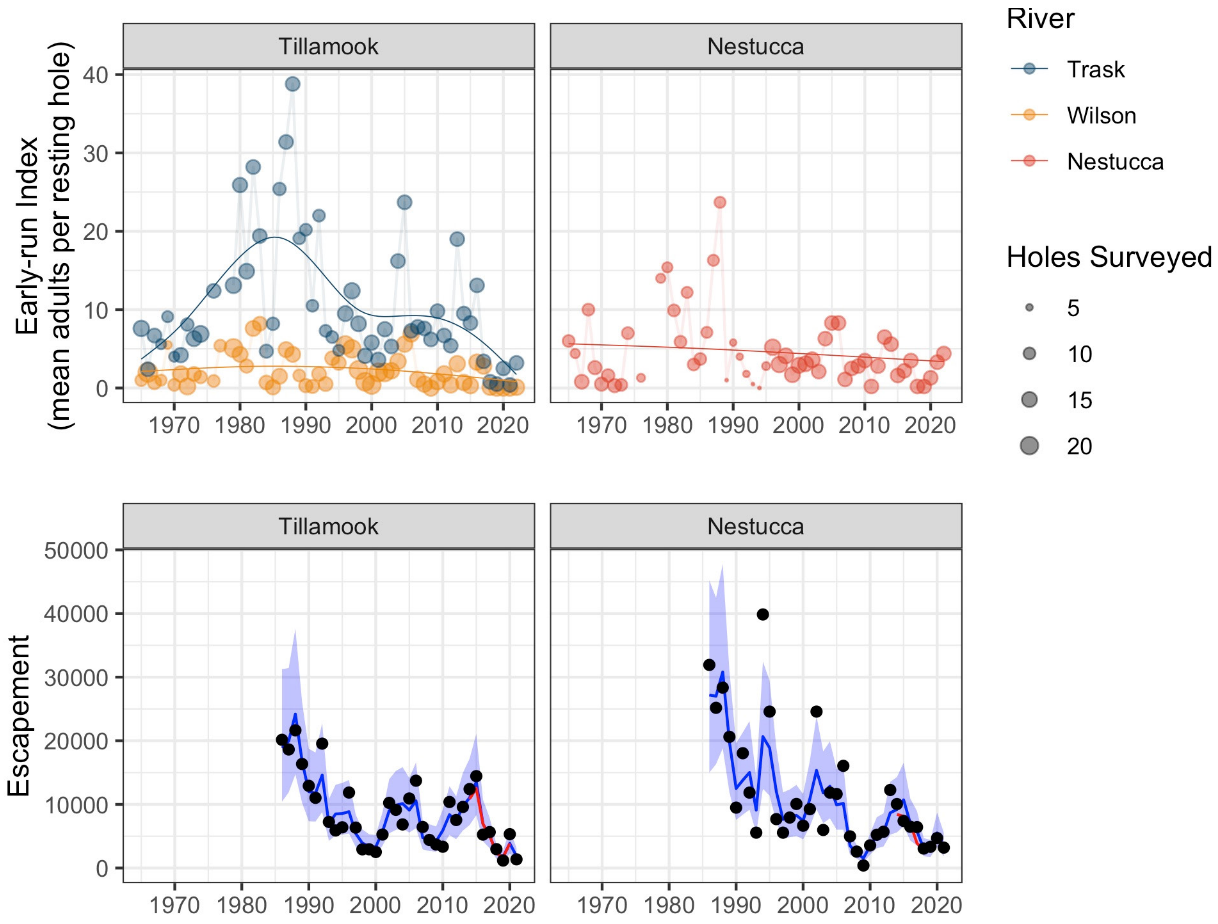

Figure 19. Early-run survey abundance estimates from August snorkel surveys (top panels) and fall-run escapement estimates (bottom panels) from the Tillamook and Nestucca River basins. In top panels, point size corresponds to survey effort and line shows generalized additive model (GAM) smooth. Bottom panel shows observations, and *MARSS*-estimated smooth for total (hatchery + natural) escapement (blue line). Red line shows natural-origin escapement estimate for 2014–20. Hatchery- and natural-origin Chinook salmon are not differentiated in these surveys (data obtained from ODFW 2023).

River, peak densities for early-run Chinook salmon are available for three river reaches (Logsden to Twin Bridges, Twin Bridges to Illahee Park, and Ojalla Bridge to Morgan Park) from 1995 to 2019 (Figure 20). Finally, the Alsea River has a float survey providing peak count information from two disjoint time periods (Figure 21): 1952–69 (one reach, Honeygrove Bridge to Schoolhouse Creek) and 1990–2019 (four reaches: Honeygrove Bridge to Schoolhouse Creek, Schoolhouse Creek to Salmonberry Park, Salmonberry Park to Digger Creek, and Digger Creek to Big Riffle Ranch Road).

Summary of OC Chinook salmon ESU demographic analyses

The Oregon Coast Chinook salmon ESU is composed predominantly—both in the number of stocks and overall numerical abundance—of fall-run Chinook salmon. Spring runs contribute a smaller but potentially important number of individuals to a subset of OC rivers.

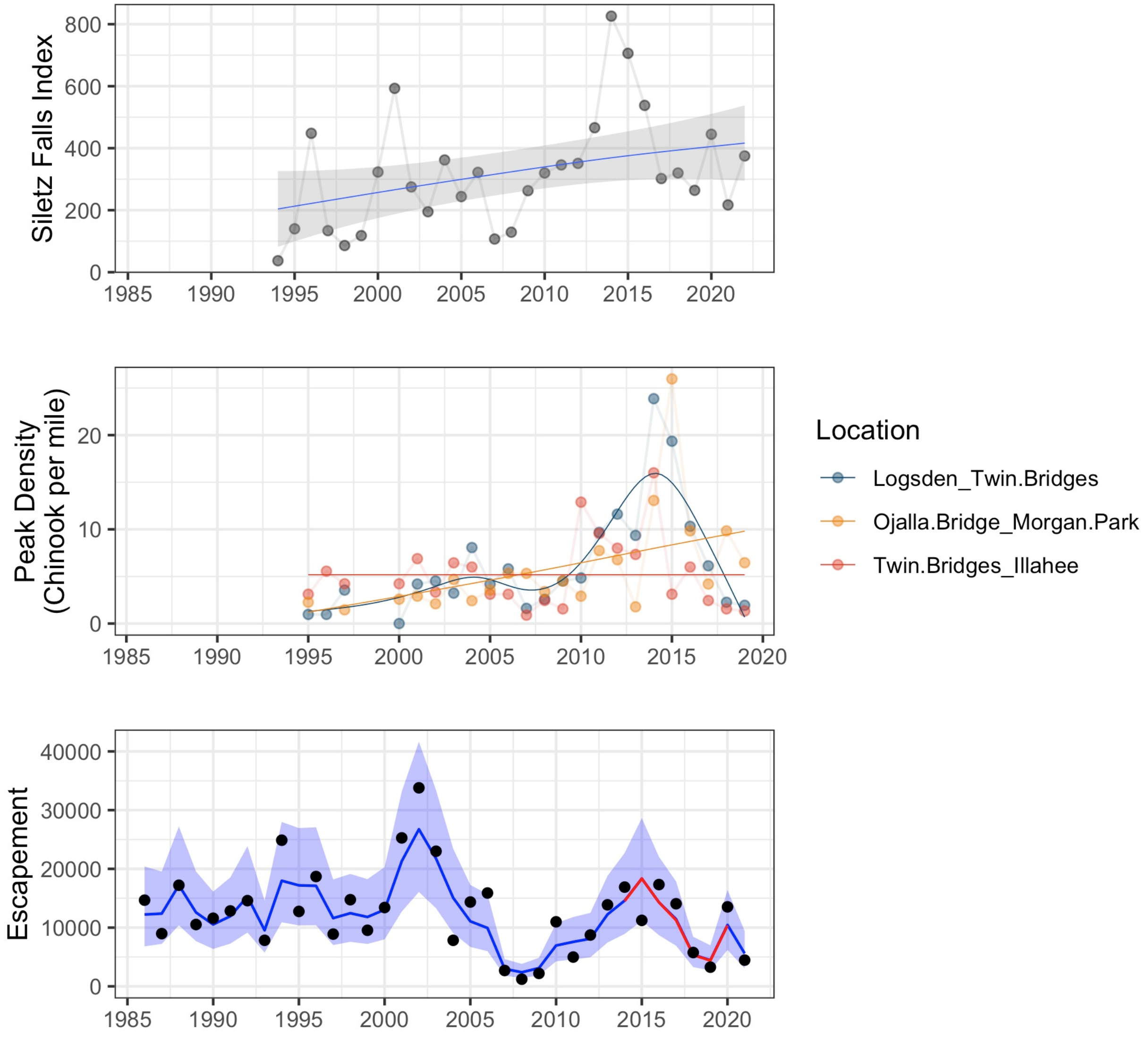

Figure 20. Early-run survey abundance estimates from float survey above Siletz Falls (top panel), snorkel surveys (middle panel), and fall-run escapement estimates (bottom panel) from the Siletz River basin. Bottom panel shows observations and *MARSS*-estimated smooth for total (hatchery + natural) escapement (blue line). Red line shows natural-origin escapement estimate for 2014–20. Counts of early run above Siletz Falls do not represent a basin-scale census estimate. Early-run Chinook salmon were not present above Siletz Falls prior to the construction of the fish ladder. Early-run Chinook salmon survey summaries (float surveys) for the Siletz River population were conducted by the Lincoln Soil and Water Conservation District and intended to target the early portion of the run (mid-to-late August–October. Surveys do not distinguish between hatchery- and natural-origin fish, but there are currently no releases of hatchery Chinook salmon into the Siletz River basin (see ODFW 2023 for additional details).

Recent information on fall-run Chinook salmon abundance (1986–2021) showed that for 14 monitored populations, 13 have spawning abundance in the thousands to tens of thousands and most have relatively stable abundances over the past 35 years (Figure 12). There are several notable exceptions to this pattern, however, with the Coquille, Tillamook, and Siuslaw River stocks at or near their lowest abundance of the time series in 2021. Overall, population trends in the most recent 15-year period (2006–21) are largely stable,

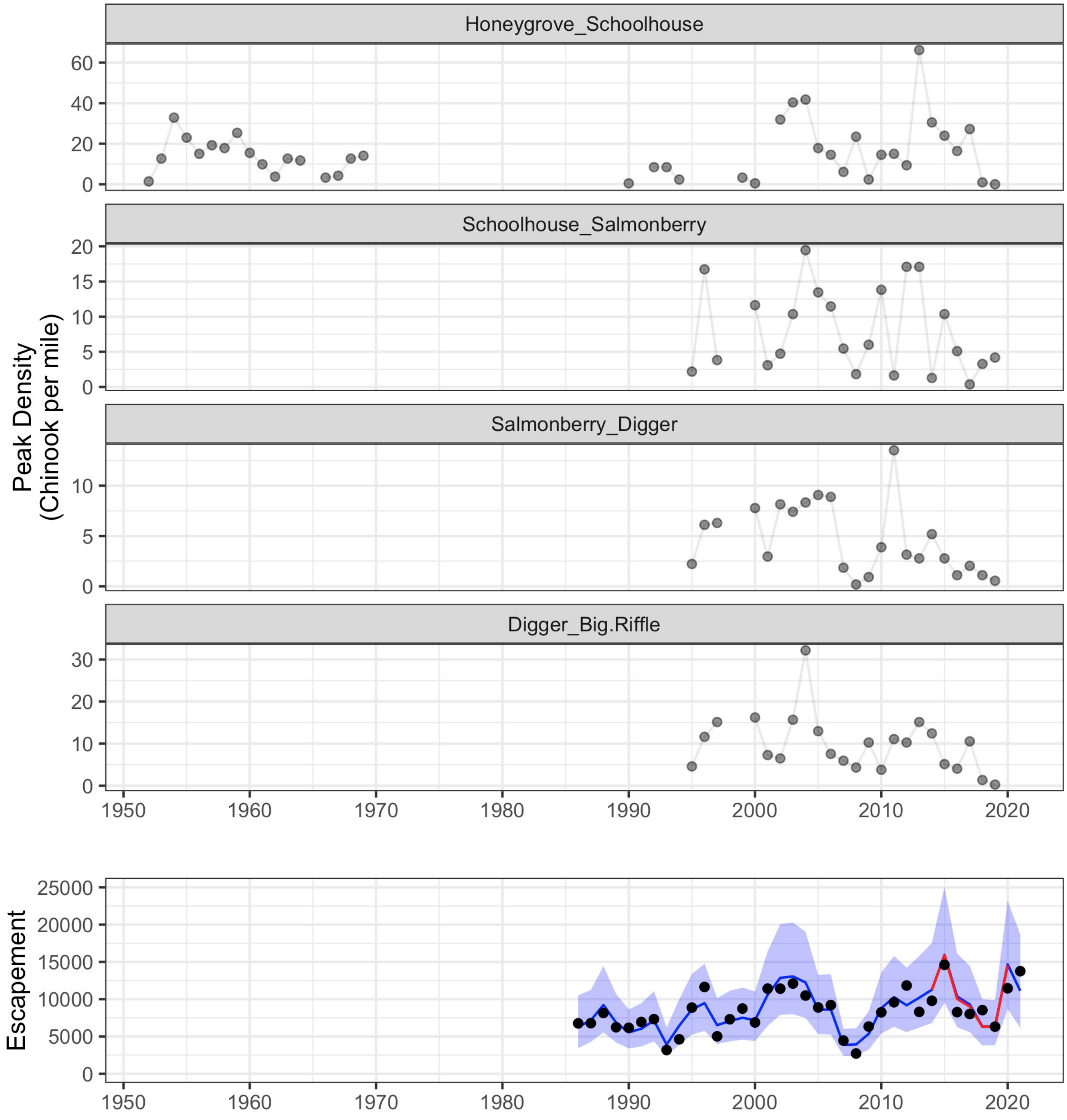

Figure 21. Early-run peak density survey estimates from float surveys of four Alsea River reaches (top four panels) and fall-run escapement estimates (bottom panel) from the Alsea River basin. Bottom panel shows observations and *MARSS*-estimated smooth for total (hatchery + natural) escapement (blue line). Red line shows natural-origin escapement estimate for 2014–20.

with point estimates of trends split evenly between positive (>0) and negative values (<0; Figure 16). This relative stability has occurred despite ocean and freshwater harvest that together capture between 40 and 50% of each cohort on average (see Risk Factor 2).

Most of the fall-run fish in this ESU are of natural origin. Only four stocks have more than a 5% contribution of hatchery-origin spawners in any one year between 2014 and 2020 (Figure 13). The two populations with a long history of substantial hatchery production (Elk and Salmon Rivers) both show a trend toward increased natural spawners since the late 1990s.

Detailed spring-run Chinook salmon data are available for two Umpqua River populations (1986–2022), both of which are much smaller than the fall-run stocks, with combined natural-origin spawners at or below 5,000 individuals in recent years (Figure 14). Longer time series are available since 1946 for spring-run fish passing Winchester Dam on the North Umpqua River, and suggest relative stability of spring-run abundance since about 1960; note that fisheries and other sources of mortality occur upstream of Winchester Dam, so abundance at the dam is not equivalent to spawning escapement. Hatchery-origin individuals contribute more to the North Umpqua River spring-run spawners than any of the fall-run stocks, but the trend is strongly toward more natural-origin spawners since 2000. Ocean harvest rates for spring-run stocks are not well documented, but are assumed to be somewhat less than harvest on fall-run Chinook salmon, since the spring run spends less time in the ocean. Freshwater (terminal) harvest data are available for the North Umpqua River spring-run population, and are estimated to be 20–30% of the in-river run size annually (see Risk Factor 2), which is comparable to fall-run in-river harvest.

In addition to the two spring-run populations with detailed abundance data, there are additional idiosyncratic survey data for early-run fish in a few other rivers (Alsea, Siletz, Tillamook, and Nestucca; Figures 19–21). While these early-run components are included in the fall-run abundance data, we also explored these data separately to see if the early run showed different trends than the full fall run. Examination of these indices of early-run abundance revealed no clear evidence that early-run trends were distinct from trends seen in the fall-run time series.

Aggregating across runs, since 1986, OC Chinook salmon spawning escapements ranged between about 45,000 and 190,000 individuals annually (Figure 18). While there have been some substantial swings in abundance over the past 35 years, the trend in aggregate abundance appears to be roughly flat. In most years, greater than 90% of spawners in the OC Chinook salmon ESU are fall-run Chinook salmon, and the vast majority are of natural origin (Table 10).

SONCC Chinook Salmon ESU

Current populations and data description

This section provides an overview of demographic data and trends for the SONCC Chinook salmon ESU. Among the Chinook salmon populations in the SONCC (Figure 1), there are subgroups based on spring and fall run timing. ODFW classifies Chinook salmon into two SMUs: Rogue Fall Chinook (RFC) and Rogue Spring Chinook (RSC). In addition to the Rogue River, RFC includes fall-run Chinook salmon from Euchre and Hunter Creeks and the Pistol, Chetco, and Winchuck Rivers. The RSC is thought to consist exclusively of spring-run fish spawning in the Rogue River upstream from the former location of the Gold Ray Dam (removed in

2010–11). In California, the Smith River and lower Klamath River (specifically Blue Creek, but also other small tributaries) contain fall-run SONCC Chinook salmon. There is also a small run of spring-run Chinook salmon in the Smith River. According to ODFW (2007b, p. 11), "a few" spring-run Chinook salmon have been observed in the Applegate, Pistol, Illinois and Chetco Rivers, but are not believed to have been historically present in large numbers.

For fall-run stocks, annual estimates of hatchery- and natural-origin escapement are available from 1986–2021 for the Oregon SONCC populations (Rogue, Chetco, Pistol, Hunter, and Winchuck Rivers). Natural- and hatchery-origin escapements are available from the lower Klamath River tributary of Blue Creek (1988–2022, except 1989 and 1993). The Smith River has had a number of surveys occurring in different parts of the river between 1980 and 2021, but no consistent systemwide estimates of spawner abundance.

In addition to spawner surveys, to monitor total fall-run abundance in the Rogue River, ODFW has conducted standardized beach seine surveys at Huntley Park since 1974 (1974–2021). Spring-run Chinook salmon in the Oregon portion of the SONCC are only monitored systematically in the Rogue River. Both natural- and hatchery-origin fish were counted passing Gold Ray Dam (1942–2010) before its removal in 2010, or near the former site of the dam (2011–22). Many of the hatchery fish passing the Gold Ray Dam site do not proceed to the primary spawning grounds, but rather return to Cole Rivers Hatchery.

Fall run

For fall-run stocks in the Oregon component of the SONCC, we have annual estimates of total and natural escapement from 1986–2021 for all rivers other than the Rogue. Estimates of natural-origin spawners are not available from Hunter Creek; we assume no hatchery contribution to that river. For the Rogue River fall run, data on total and natural-origin escapement are available for the lower Rogue component of the river but not for other river tributaries (e.g., Applegate, Illinois, Middle Rogue, Upper Rogue). ODFW provided an aggregate estimate of total (sum of natural- and hatchery-origin escapement) fall-run fish in the entire Rogue River basin. We used the proportion of fish of hatchery origin measured at Huntley Park as the measure of for the proportion of natural-origin spawners. The major source of fall-run hatchery fish in the Rogue River is near but downstream from Huntley Park at Indian Creek Hatchery. Available information suggests that historically there were few hatchery-origin spawners in the Applegate, Illinois, Upper Rogue, and Middle Rogue tributaries, with only a few years of modest hatchery releases of fall-run fish in the Middle and Upper Rogue Rivers during the 1980s (ODFW 2013). As a result, we expect that the natural-origin fraction measured at Huntley Park slightly underestimates the natural-origin fraction in the entire basin. However, it is the only source of data we have available.

For the California component, we have escapement data from the lower Klamath River (Blue Creek) from 1988–2022, but are missing data in 1989 and 1993. Blue Creek has a negligible hatchery contribution. The Smith River has limited escapement estimates but does have a few sonar estimates of abundance at the river mouth (for 2010, 2011, 2014, and 2021) along with redd counts and indices based on visual detections for subsets of the river with spatially and temporally patchy coverage. Some estimates of hatchery contributions to recreational harvest in the Smith River are available, but they are not representative of the basin as a whole. In general, estimated hatchery contributions to Smith River Chinook salmon harvest from years when Rowdy Creek Hatchery production was marked have been low, and decrease with distance between the sampling site and the hatchery.

In addition to escapement estimates, migrating fall-run Chinook salmon are enumerated at Huntley Park near the mouth of the Rogue River (1974–2021). These are all spawning fish, but not all of these fish will spawn due to fisheries and other mortality sources upstream of Huntley Park. The proportion of hatchery fish at Huntley Park is also available from 1974–2021, but these estimates do not correspond to spawner proportions due to differences in the destination of hatchery- and natural-origin spawners within the river relative to spawning habitat.

The Smith River dual-frequency identification sonar (DIDSON) sampling location is located upstream of the confluence with Rowdy Creek, so the DIDSON river run-size estimate does not include fish taken in by Rowdy Creek hatchery or natural-origin fish spawning in Rowdy Creek. Apportionment of salmonids passing the sampling location may be categorized to species by date (with salmonids passing before 15 December assumed to be Chinook salmon, and steelhead thereafter) or based on the species composition observed in creel surveys or at Rowdy Creek weir. The different methods typically agreed within 10–15% for years when multiple methods were compared.

Spring run

The only regular escapement data on the spring-run stocks in the SONCC are from the Rogue River. Annual estimates of natural escapement are available from counts of fish passing Gold Ray Dam (or its former site since removal in 2010–11; 1942–2022).

Visual surveys for putatively spring-run Chinook salmon on the Smith River take place during the summer (Hanson 2021). Volunteer snorkel surveys covering varying portions of the Smith River can be used to develop an index of spring Chinook salmon spawners observed per stream mile surveyed for 1982–2020 (South Fork) or 1989–2019 (Middle Fork).

Trend analyses

Trends were analyzed using the same methods as were described above for the OC Chinook salmon ESU.

For the fall-run populations with sufficient escapement data, we constructed the model using total escapement data for each river (Figure 22) and then summed across the smoothed estimates to provide an estimate of portion of the aggregate ESU abundance (not including the Smith River) from 1986–2021 (Figures 27 and 28). We constructed a separate DLM for fall-run data from Huntley Park using hatchery and natural abundance as separate populations (Figure 23).

For spring-run Chinook salmon with sufficient escapement data (i.e., in the Rogue River), we treated hatchery and natural populations as separate stocks within the DLM (Figure 24).

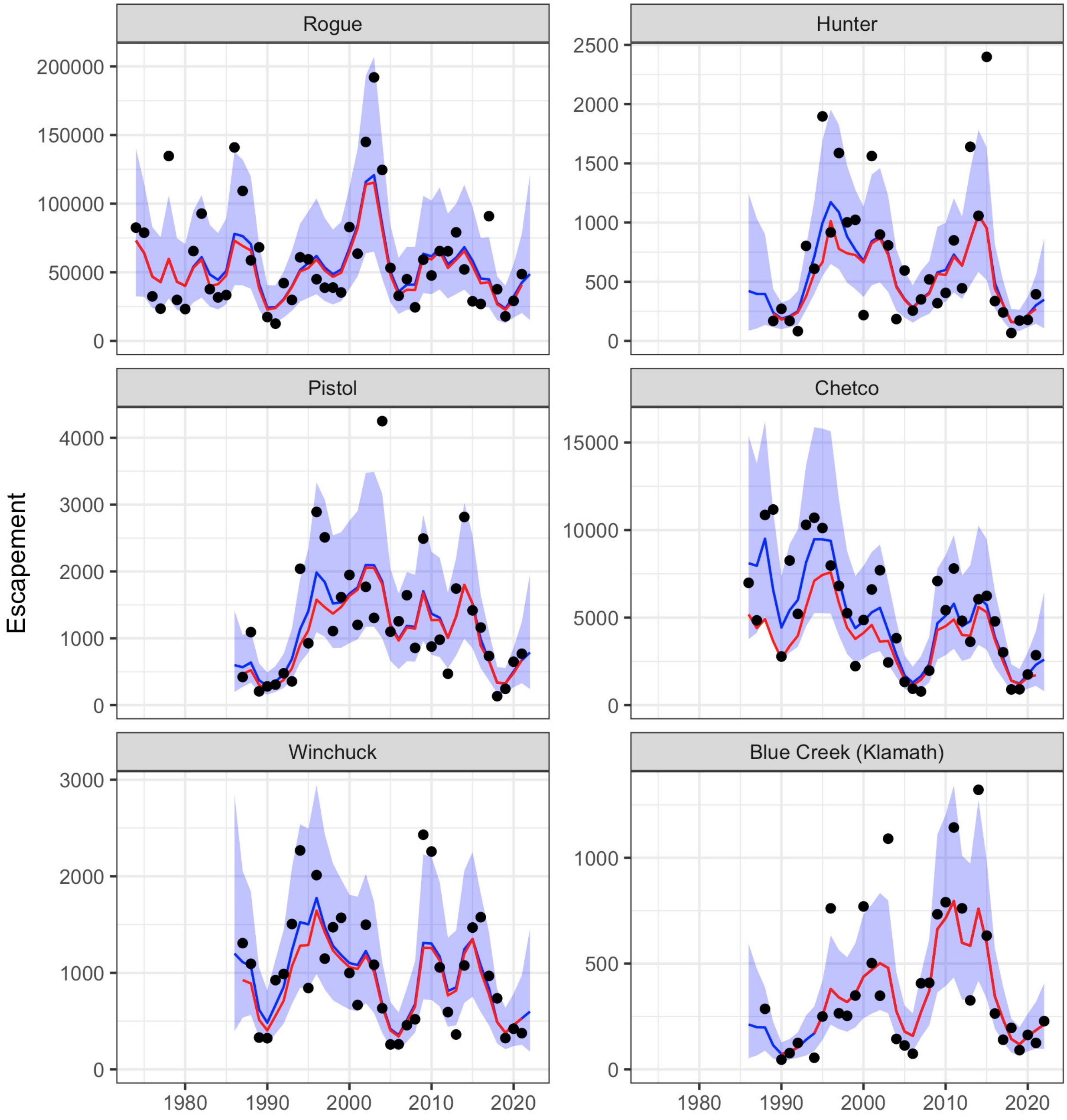

Figure 22. Total escapement (natural + hatchery) for fall-run populations in the SONCC Chinook salmon ESU. Points show observations, blue line and shaded area show model predictions of abundance and 95% CI. Natural escapement estimates are shown in red.

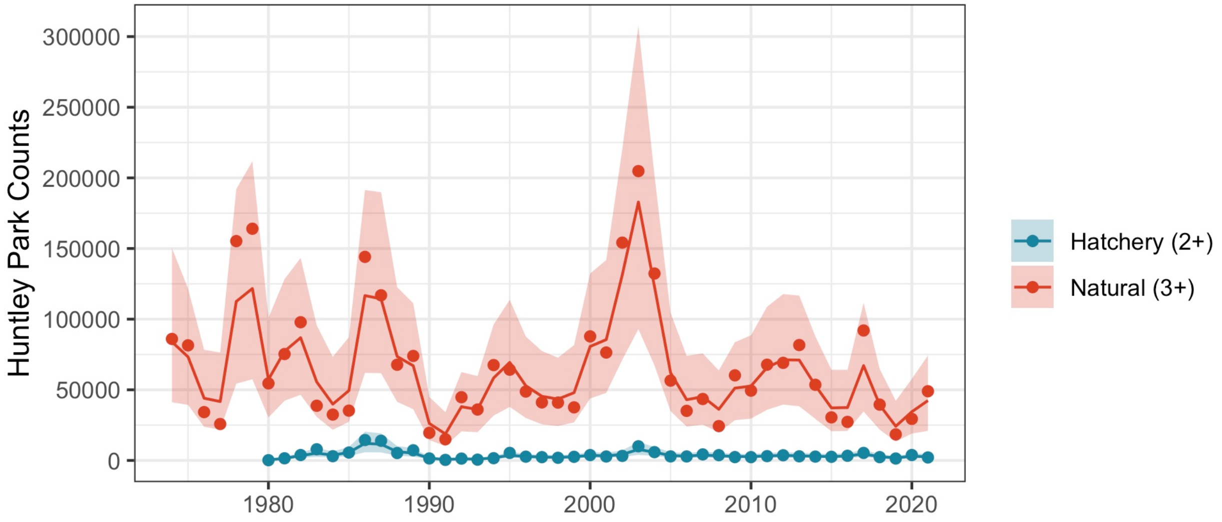

Figure 23. Natural (ages-3+) and hatchery (ages-2+) abundances for Rogue River fall Chinook salmon passing Huntley Park. Points show observations, line and shaded area show model predictions of abundance and 95% CI.

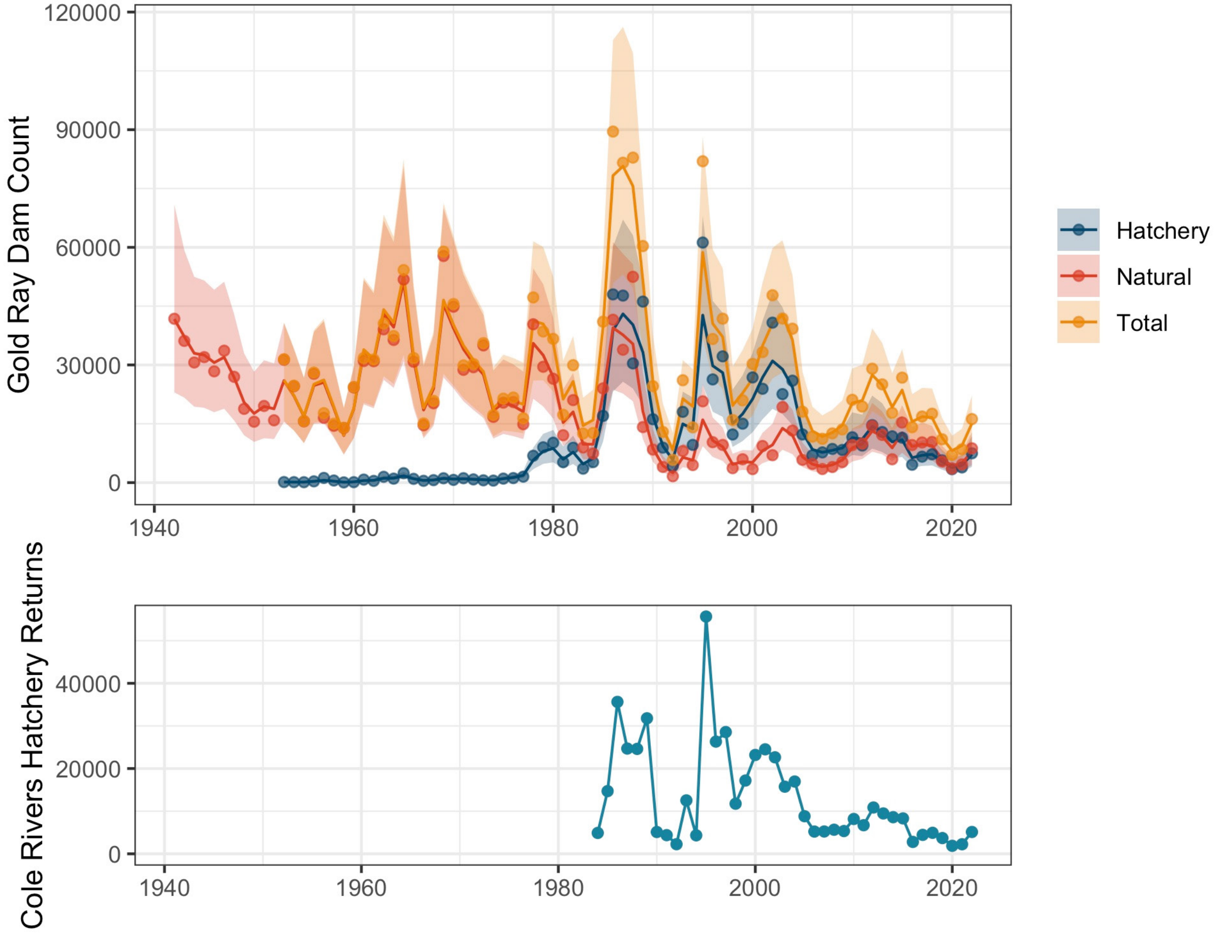

Figure 24. Abundance time series for natural-origin, hatchery-origin, and total (hatchery + natural) Chinook salmon passing Gold Ray Dam (top) and hatchery returns to Cole Rivers Hatchery (bottom). Points show observations, lines and shaded areas show model predictions of abundance and 95% CI. According to ODFW analyses (O'Malley 2020a), for the period of 2016–18, the run-timing composition at the former Gold Ray Dam site consists of approximately 63% spring run, 7% fall run, and 30% mixed run Chinook salmon.

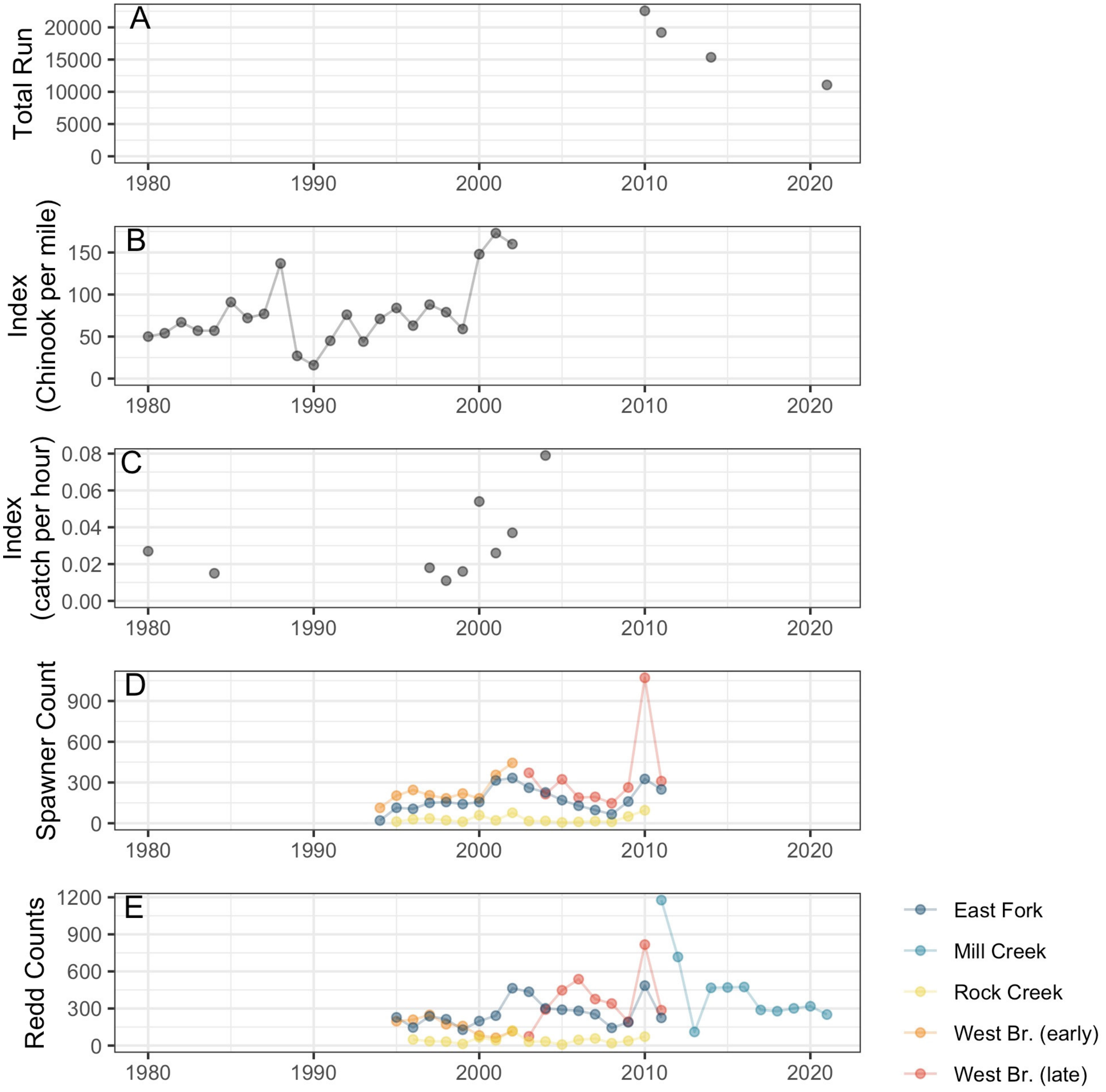

Figure 25. Indices of abundance for Smith River fall-run Chinook salmon. A) Total run size estimated via DIDSON near the river mouth. B) Spawner surveys from a 1.7-mile stretch of Mill Creek (Waldvogel 2006). C) Chinook creel survey catch per unit effort (Zuspan 2018). D) Spawner count indices from four river reaches. E) Redd counts from 5 river reaches. In E), 2011+ data reflect a larger area than the previous years.

We present only graphical analyses for Smith River because we only had estimates of the total upstream run for four disjunct years, which did not support fitting DLM for fall-run populations (Figure 25). The spring-run snorkel surveys covered a longer time period, but contain many zero observations and have variable survey effort, so are difficult to interpret (Figure 26).

We calculated 15-year trends using linear regression of year against log-transformed escapement estimates from the DLM model against years (Figure 29; Tables 13–15).

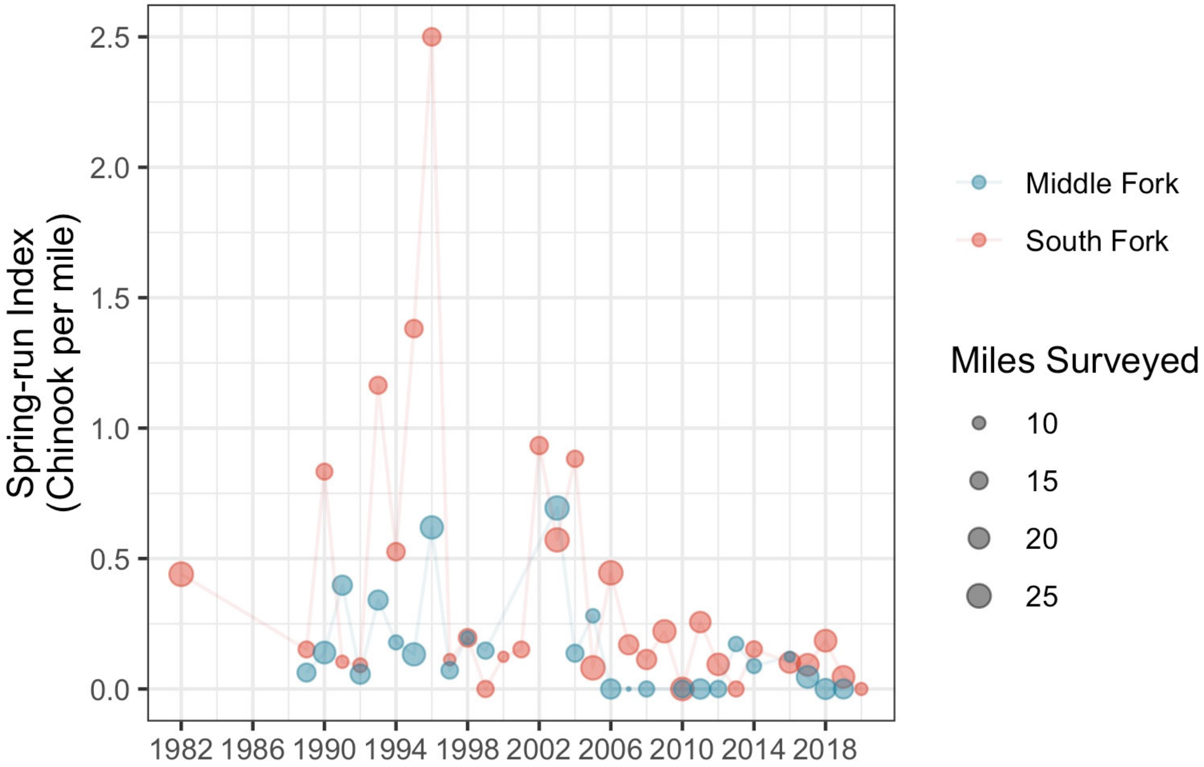

Figure 26. Indices of abundance for Smith River spring-run Chinook salmon. Snorkel surveys of the Middle and South Fork Smith River. Data from Hanson (2021).

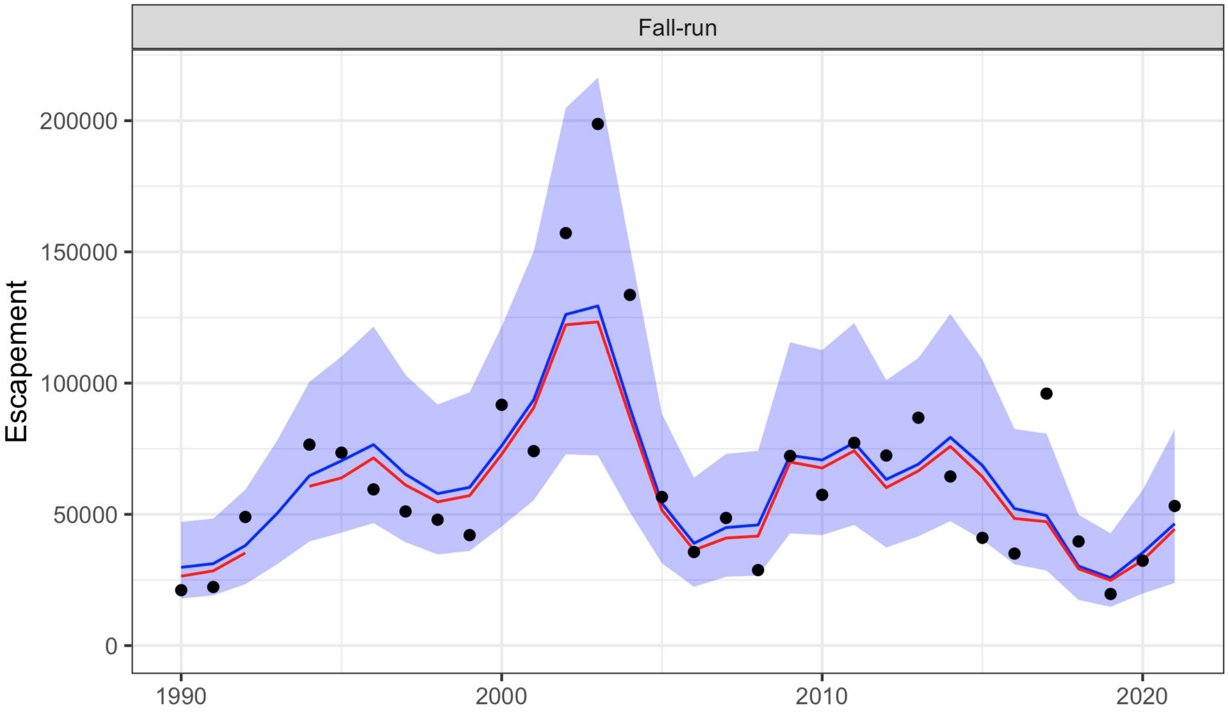

Figure 27. Escapement time-series summed across all SONCC for fall-run Chinook salmon (excluding the Smith River; total in blue, natural-origin in red). Points show observations and lines indicate the smoothed estimates from DLM. Smith River is not included due to limited availability of total escapement estimates, but would add ~10–20,000 mostly natural-origin spawners in years with data available.

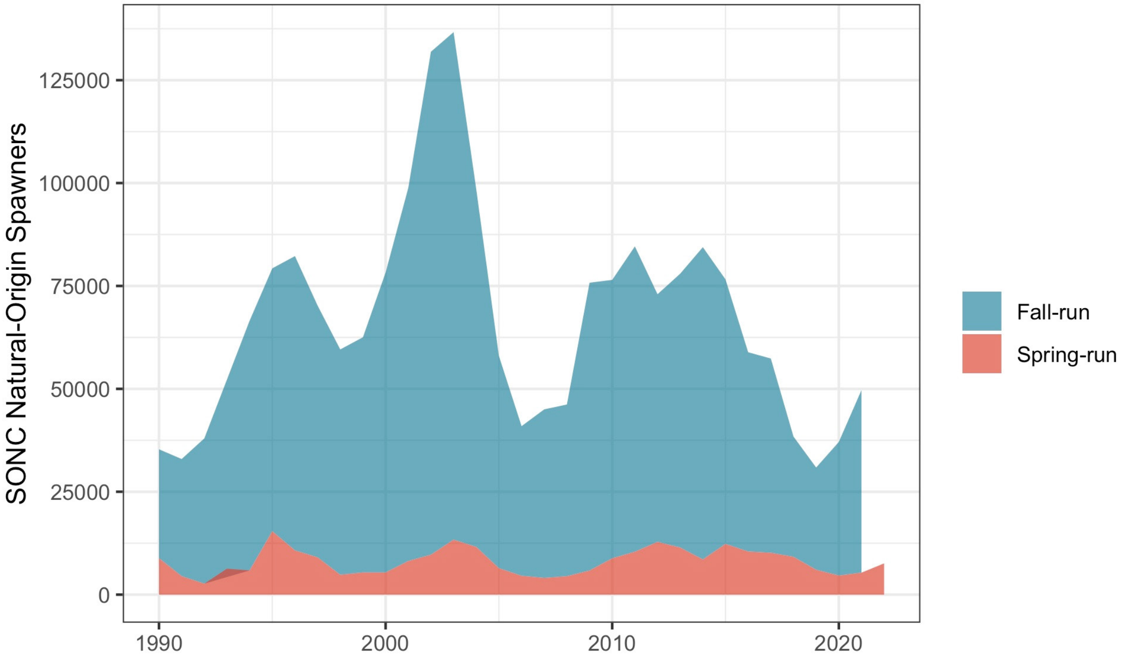

Figure 28. Natural escapement time series summed across all SONCC fall- and spring-run Chinook salmon (excluding the Smith River). Posterior means of the smoothed estimates from DLM shown. Estimates for some fall-run stocks are missing prior to 1990 and therefore not shown. Smith River is not included due to limited availability of total escapement estimates, but would add ~10–20,000 mostly natural-origin spawners in years with data available.

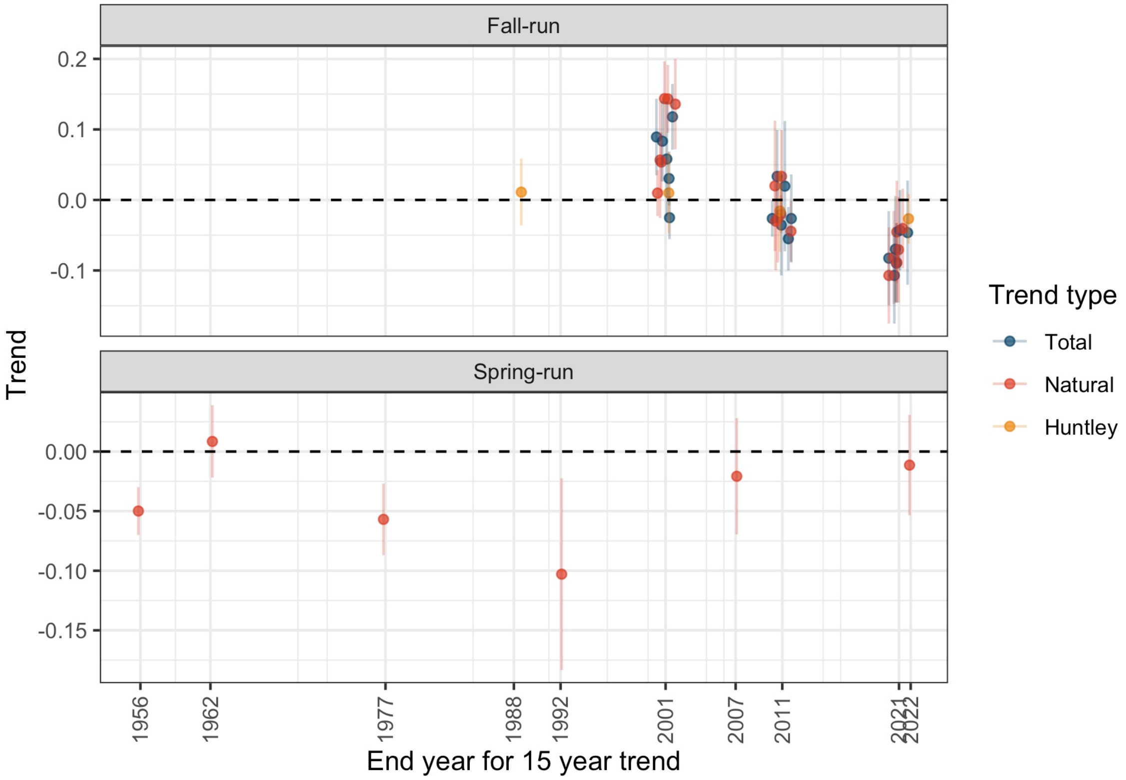

Figure 29. 15-year trends estimated for fall-run (natural escapement, total escapement, and passage at Huntley Park) and spring-run stocks (natural escapement passing Gold Ray Dam). Points show estimated trend through time and 95% CI for individual stocks (points are located at the end of each 15-year period). Points have been slightly jittered to reduce overlap.

Table 13. 15-year trends (slope) in log total and log natural-origin spawner abundance for fall-run stocks computed from a linear regression applied to the smoothed spawner log abundance estimate versus year. In parentheses are the upper and lower 95% CIs. Only populations with at least four spawner estimates and with at least two data points (observations, not estimates) in the first five years and last five years of the 15-year ranges are shown.

Population	1974–88	1986–2001	1997–2011	2007–21
Rogue R. (Total)	0.01(−0.01,0.04)	0.02(−0.03,0.06)	−0.01(−0.06,0.03)	−0.04(−0.07,−0.01)
Rogue R. (Natural)	0.01(−0.02,0.03)	0.02(−0.02,0.06)	−0.01(−0.06,0.03)	−0.04(−0.07,0.00)
Hunter R. (Total)	n/a	0.09(0.04,0.14)	−0.05(−0.09,−0.01)	−0.07(−0.13,−0.01)
Hunter R. (Natural)	n/a	0.14(0.09,0.18)	−0.04(−0.08,0.00)	−0.07(−0.14,−0.01)
Pistol R. (Total)	n/a	0.11(0.07,0.16)	−0.03(−0.05,0.00)	−0.09(−0.14,−0.04)
Pistol R. (Natural)	n/a	0.14(0.10,0.18)	−0.02(−0.04,0.01)	−0.09(−0.13,−0.04)
Chetco R. (Total)	n/a	−0.02(−0.05,0.01)	−0.04(−0.10,0.02)	−0.05(−0.11,0.01)
Chetco R. (Natural)	n/a	0.01(−0.02,0.04)	−0.04(−0.09,0.02)	−0.05(−0.11,0.01)
Winchuck R. (Total)	n/a	0.03(−0.01,0.07)	−0.03(−0.08,0.02)	−0.04(−0.09,0.00)
Winchuck R. (Natural)	n/a	0.05(0.01,0.09)	−0.03(−0.08,0.02)	−0.04(−0.09,0.01)
Blue Creek[a] (Total)	n/a	0.09(0.04,0.13)	0.03(−0.02,0.08)	−0.10(−0.16,−0.04)
Blue Creek[a] (Natural)	n/a	0.13(0.08,0.18)	0.03(−0.02,0.08)	−0.10(−0.16,−0.04)

[a] Blue Creek is a tributary of the Klamath River.

Table 14. 15-year trends (slope) in log total and log natural-origin spawner abundance for the Rogue River fall run measured at Huntley Park, computed from a linear regression applied to the smoothed spawner log abundance estimate versus year. In parentheses are the upper and lower 95% CIs.

Population	1974–88	1987–2001	1997–2011	2007–21
Rogue R. (Huntley Park)	0.01(−0.04,0.06)	0.01(−0.05,0.07)	−0.02(−0.07,0.04)	−0.03(−0.06,0.01)

Table 15. 15-year trends (slope) in log natural spawner abundance for the Rogue River natural-origin spring-run stock computed from a linear regression applied to the smoothed natural spawner log abundance estimate versus year. In parentheses are the upper and lower 95% CIs.

Population	1942–56	1948–62	1963–77	1978–1992	1993–2007	2008–2022
Rogue River	−0.05 (−0.07,−0.03)	0.01 (−0.02,0.04)	−0.06 (−0.09,−0.03)	−0.10 (−0.18,−0.02)	−0.02 (−0.07,0.03)	−0.01 (−0.05,0.03)

The proportion of the natural spawning escapement estimated to be of natural origin was generally above 0.75 (Figure 30).

We calculated geometric means for each five-year period using output from the DLM (Tables 16–18).

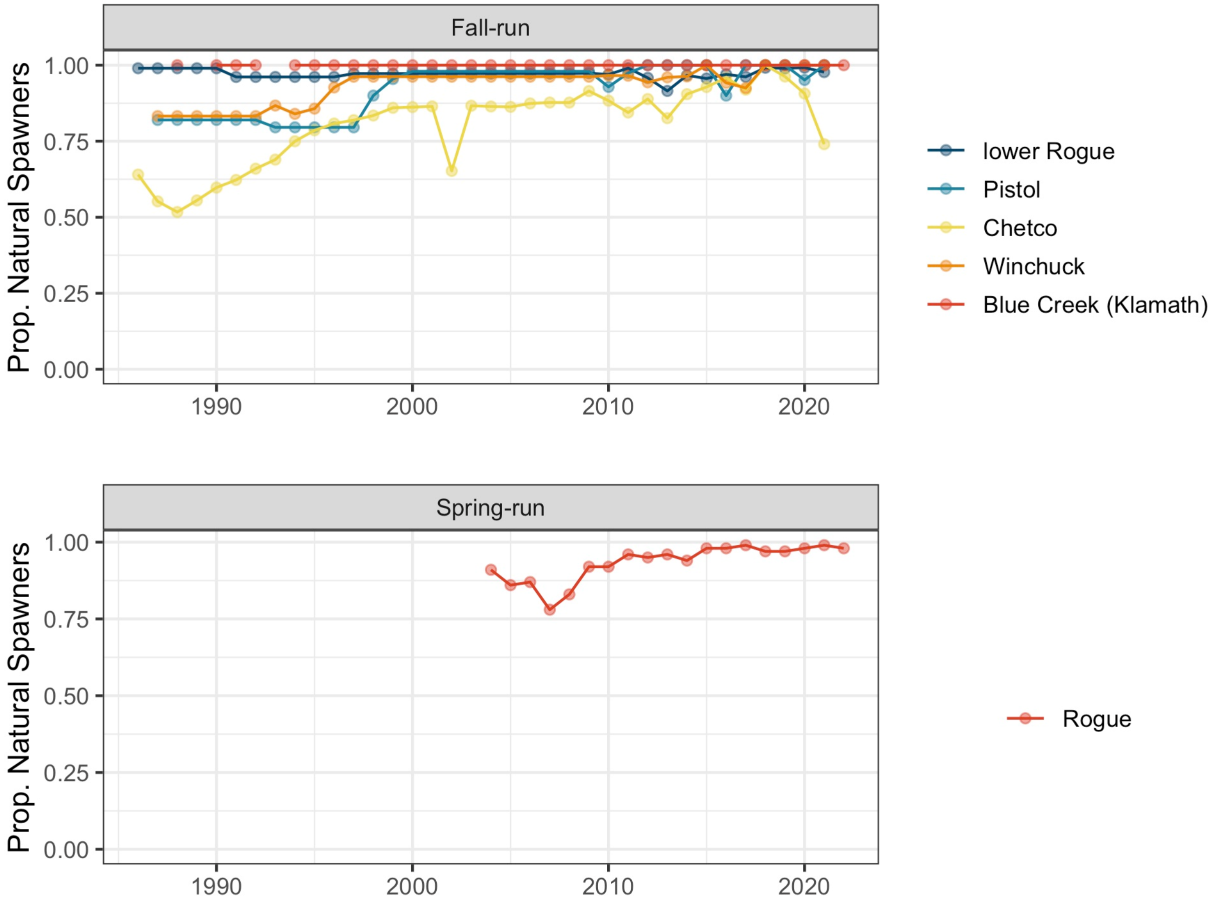

Figure 30. Proportion of natural-origin spawners for all populations in the SONCC Chinook salmon ESU, plotted by their respective management units. For Blue Creek, formal annual estimates of hatchery contributions are not reported, but no ad-clipped fish have been observed in at least 19 years of snorkel or carcass surveys (A. Antonetti, Yurok Tribe Fisheries Biologist, personal communication).

Table 16. Five-year geometric mean of populations in the Rogue River fall Chinook salmon management group. Smoothed natural-origin spawner estimates are shown. In parentheses, the 5-year geometric mean of smoothed total spawners (blue lines in graphs) are shown. An entry with only values in parentheses indicates that no fraction natural-origin estimates were available for that population. Geometric mean was computed as the product of counts raised to the 1/(number of values in band).

Population	1986–90	1991–95	1996–2000	2001–05	2006–10	2011–15	2016–20
Rogue River	49,153 (52,999)	37,882 (38,930)	54,360 (56,668)	83,688 (86,693)	44,141 (47,198)	59,404 (62,057)	31,709 (33,608)
Blue Creek (Klamath)	120 (147)	140 (140)	365 (365)	355 (355)	375 (375)	658 (658)	185 (185)
Chetco River	4,050 (7,094)	5,235 (7,489)	4,999 (5,976)	2,952 (3,612)	2,309 (2,609)	4,702 (5,358)	1,899 (2,001)
Pistol River	365 (473)	574 (712)	1,496 (1,697)	1,727 (1,763)	1,220 (1,258)	1,365 (1,372)	501 (516)
Winchuck River	644 (845)	929 (1,099)	1,283 (1,344)	800 (832)	703 (730)	1,029 (1,065)	581 (598)
Hunter River	n/a	369 (446)	773 (896)	606 (619)	413 (426)	826 (830)	237 (242)

Table 17. Five-year geometric mean of Rogue River fall-run Chinook salmon measured at Huntley Park. Smoothed natural-origin spawner estimates are shown. Geometric mean was computed as the product of counts raised to the 1/(number of values in band).

Population	1974–78	1979–83	1984–88	1989–93	1994–98	1999–2003	2004–08	2009–13	2014–18
Rogue R. (Huntley Park)	65,853	76,514	72,012	33,780	53,056	95,301	55,504	61,446	45,429

Table 18. Five-year geometric mean of Rogue River spring-run Chinook salmon (1977–2022). Smoothed natural-origin spawner estimates are shown. Geometric mean was computed as the product of counts raised to the 1/(number of values in band).

Population	1943–47	1948–52	1953–57	1958–62	1963–67	1968–72	1973–77	1978–82
Rogue River (hatchery)	n/a	n/a	223	298	1,035	869	1,028	7,115
Rogue River (natural)	32,969	20,366	22,755	21,371	34,675	33,916	20,565	24,338
Population	**1983–87**	**1988–92**	**1993–97**	**1998–2002**	**2003–07**	**2008–12**	**2013–17**	**2018–22**
Rogue (hatchery)	15,343	16,508	23,610	21,562	14,251	10,593	9,188	5,454
Rogue (natural)	19,974	9,062	8,941	6,308	7,319	7,864	10,368	6,261

Summary of SONCC Chinook salmon ESU demographic analyses

We received data on six populations of fall-run and one population of spring-run Chinook salmon from the SONCC, spanning from the late 1980s through 2021 or 2022. Importantly, we were unable to find extended time-series information on the Smith River population, , so the Smith River is excluded from our time-series analysis even though this population is thought to contribute thousands of individuals to the ESU.

The SONCC Chinook salmon ESU is dominated in abundance by the large Rogue River system, with annual abundances of 25,000 to 120,000 fall-run spawners (Figure 22) and 5–30,000 spring-run spawners (Figure 24) in the Rogue River alone. The remaining five fall-run populations with data each have typically fewer than 10,000 spawners annually.

Trends for all fall- and spring-run populations were estimated to be slightly negative for the most recent 15-year period (Figure 29). Collectively, the fall-run populations are estimated to be around 50,000 in 2021 (Figure 27), which is similar in abundance to other troughs in the time series (e.g., 1990–91, 2006–08). Direct estimates of ocean harvest are not available for SONCC Chinook salmon populations, but a proxy for ocean harvest (fall-run Chinook salmon from the Klamath river) suggests a relatively stable harvest rate through time (mostly 20% or below)—though since 2018, ocean harvest of this proxy has been around 30% (see Risk Factor 2). Terminal (estuary and in-river) harvest varies somewhat among rivers (see Risk Factor 2), but has also been relatively stable (near 10% annually) for most rivers except for the Chetco, which averages about 20%.

The natural-origin spring run in the Rogue River appears to have been relatively stable at about 10,000 or fewer spawners since approximately 1990 (Figure 24). This is considerably lower than the pre-1990 abundance, which was typically >15,000 and commonly >30,000. ODFW (2007, 2019) attributes this decline to delayed effects of the Lost Creek Dam, which was constructed in 1977. Ocean harvest rates for spring-run Chinook salmon are not well known, but are thought to be lower than harvest rates on SONCC fall-run populations because the spring run spends less time in the ocean. In-river harvest varied from <2% to 35% between 2004 and 2018, with total harvest of <15% between 2008 and 2018 (see Risk Factor 2). Overall, harvest has not shown a notable trend for either fall- or spring-run populations in recent years.

Available data suggest that the proportion of natural-origin spawners was high for all fall- and spring-run populations throughout the time series (>70%; Figure 30). This occurs despite substantial hatchery production for both fall- and spring-run Chinook salmon in the Rogue River. For the spring-run population, this can be explained by the spatial separation of the natural spawning grounds and the location of Cole Rivers Hatchery. For the fall run, a lack of monitoring data for fish by natural vs. hatchery origin (with the notable exception of the lower RogueRiver; Figure 30) makes it difficult to determine the exact contribution of fall-run hatchery fish to natural spawners in the Rogue River.

Data for the Smith River, a sizable population, were insufficient to evaluate trends. Several estimates for the Smith River from 2010 to 2021 were between 10,000 and 20,000 fall-run Chinook salmon, suggesting that it is likely the second-largest population in the SONCC. If these numbers are accurate, that would suggest the overall spawner abundance for SONCC was 60–70,000 spawners in 2021.

Analysis of ESA Section 4(a)(1) Factors

Section 4(a)(1) of the ESA directs NMFS to determine whether any species is threatened or endangered because of any of the following factors: 1) the present or threatened destruction, modification, or curtailment of its habitat or range; 2) overutilization for commercial, recreational, scientific, or educational purposes; 3) disease or predation; 4) the inadequacy of existing regulatory mechanisms to address identified threats; or 5) other natural or man-made factors affecting its continued existence. Section 4(b)(1)(A) requires us to make listing determinations after conducting a review of the status of the species and taking into account efforts to protect such species.

NMFS has previously reviewed the impacts of various factors contributing to the decline of Pacific salmon and steelhead in previous listing determinations (e.g., USOFR 1998, 2004) and supporting documentation (NMFS 1996, 1997, 1998). These Federal Register notices and technical reports concluded that all of the factors identified in Section 4(a)(1) of the ESA had played a role in the decline of U.S. West Coast Chinook salmon stocks. NMFS also reviewed and provided a detailed analysis of these factors for the ESA-listed OC and SONCC coho salmon ESUs, which overlap with the OC and SONCC Chinook salmon ESUs (Stout et al. 2012, NMFS 2014, 2016a, 2022a). Because so much effort has gone into identifying freshwater and estuarine habitat threats to OC and SONCC coho salmon, this section draws largely from these documents, after first discussing some important similarities and differences between how coho and Chinook salmon utilize freshwater and estuarine habitats.

Coho and Chinook salmon have similarities and differences in their life-history strategies. Thinking about the most basic components of life history for both species—adult holding, spawning, incubation, rearing, and smolt outmigration—we find that certain life stages occur at similar times. The typical incubation period for eggs of both species is in the fall and winter. However, there are spatial and temporal differences between the species. Chinook salmon typically spawn earlier, starting in the summer and proceeding through the fall and early winter, while coho salmon spawn starting in the fall/early winter and proceed through early spring (Groot and Margolis 1991). Spawning location will both overlap and vary, with Chinook salmon occupying the larger main rivers (greater than 20 m bankfull width) as well as the lower portions of tributaries (Stein et al. 1972, Beechie 2021). Coho salmon will be in the lower portions as well as the upper portions of tributaries (Stein et al. 1972). Elevation, stream temperature, channel type, stream size, stream channel gradient, depth, velocity, and streambed particle size all play a role in the spatial segregation between coho and Chinook salmon spawning (Montgomery et al. 1999, Beechie et al. 2008, Austin et al. 2023). Shared spawning occupancy between Chinook and coho salmon can occur in over one-third of a watershed. Larger body size in Chinook salmon allows for spawning utilization of larger river habitats.

With respect to life-history strategies and associated habitat types, similarities increase from the fry to parr stage for coho and Chinook salmon (Austin et al. 2023). Overlap occurs in tributaries and mainstem rivers, with Chinook salmon generally being in higher densities in larger rivers, and coho salmon in higher densities in tributaries (Stein et al. 1972, Beechie et al. 2005, Beechie 2021). Both species also use floodplains; however, the density of juvenile coho salmon will be higher in slower-water environments such as beaver ponds, marshes, and sloughs (Beechie 2021). From a seasonal perspective, both coho and Chinook salmon will be in higher densities in the estuary during the spring and summer versus the fall and winter (Hall et al. 2023). The proportion of each species that is fry, parr, sub-yearling, and yearling will vary, but in general yearling coho salmon are the dominant life-history strategy, while fry, parr, and sub-yearling Chinook salmon typically dominate in terms of proportion of total life-history strategy.

Risk Factor 1: The Present or Threatened Destruction, Modification, or Curtailment of Its Habitat or Range

Our previous Federal Register notices and reports (cited above), as well as numerous other reports and assessments (Kostow 1995, Nicholas et al. 2005, ODFW 2007b, 2014a), have reviewed in detail the effects of historical and ongoing land-management practices that have altered Oregon coastal salmon habitat.

A major determinant of salmon status is the condition of the freshwater, estuarine, and ocean habitats on which salmon depenD.Chinook salmon depend on suitable freshwater, estuarine, and marine habitat, each of which influences population abundance, productivity, diversity, and spatial structure (McElhany et al. 2000). Considering the whole U.S. West Coast, a broad range of historical and ongoing land and water-management activities and practices have often adversely impacted the freshwater and estuarine habitats used by Chinook salmon, including construction of dams and other barriers, water diversions, channelization and diking, agricultural practices, roads, timber harvest, and urbanization. These activities have altered, or in some cases eliminated, habitat for OC and SONCC Chinook salmon.

Below, we summarize the key habitat-related factors that may be limiting the viability of the OC and SONCC Chinook salmon ESUs.

OC Chinook salmon ESU

In the recent five-year review for OC coho salmon (NMFS 2022a), many of the factors identified above continue to be described as habitat concerns that potentially impact salmonid viability. For coho salmon, insufficient stream juvenile rearing habitat complexity—including lack of large wood debris, pools, and connections to floodplains and off-channel areas, especially overwintering habitat—is a problem throughout the Oregon coast. Because OC Chinook salmon juveniles rarely overwinter in freshwater, these issues may be less impactful to Chinook than to coho salmon, however. Poor water quality, with high summer temperatures and agricultural runoff, has also been identified as an issue throughout the Oregon coast. Lack of fish passage (tide gates) and access to estuarine off-channel habitat is a widespread problem.

Stream complexity

The loss of stream complexity has been identified as one of the key factors limiting the distribution and abundance of salmon in both coho and Chinook salmon status reviews (OCSRI 1997, NMFS 1997, 1998, Myers et al. 1998, Stout et al. 2012, ODFW 2021). Stream complexity can be defined as the ability of a stream to provide a variety of habitats

Table 19. Primary and secondary limiting factors for OC Chinook salmon ESU river and stream basins. Adapted from the Oregon Coast Coho Conservation Plan (ODFW 2007a).

Basin	Primary limiting factor	Secondary limiting factor(s)
Necanicum River	Stream complexity	None identified
Nehalem River	Stream complexity	Water quality
Tillamook River	Stream complexity	Water quality
Nestucca River	Stream complexity	None identified
Salmon River	Hatchery impacts	Stream complexity
Siletz River	Stream complexity	None identified
Yaquina River	Stream complexity	Water quality
Beaver River	Spawning gravel	Stream complexity
Alsea River	Stream complexity	Water quality
Siuslaw River	Stream complexity	Water quality
Lower Umpqua River	Stream complexity	Water quality
Middle Umpqua River	Water quantity	Stream complexity, water quality
North Umpqua River	Hatchery impacts	Stream complexity
South Umpqua River	Water quantity	Stream complexity, water quality
Siltcoos River	Nonindigenous species	Stream complexity, water quality
Tahkenitch River	Nonindigenous species	Stream complexity, water quality
Tenmile River	Nonindigenous species	Stream complexity, water quality
Coos River	Stream complexity	Water quality
Coquille River	Stream complexity	Water quality
Floras Creek	Stream complexity	Water quality
Sixes River	Stream complexity	Water quality

(ODFW 2007a). ODFW's Oregon Coast Coho Assessment (Nicholas et al. 2005) identified stream complexity as either a primary or secondary limiting factor throughout all basins of the ESU (Table 19). In addition to stream complexity, water quality, water quantity, hatchery impacts, spawning gravel, and exotic species were identified as limiting factors (ODFW 2007a).

One of the leading historical causes for the loss of stream complexity was the practice of using streams to transport logs. From the 1880s through the 1950s, the private timber industry used splash damming as a common method of log transport in western Oregon (Miller 2010). A splash dam was a temporary wooden dam that was used to control the level of water and float more logs downstream. When ready, the logging company would open the splash dam or sometimes blow it with dynamite, sending a cascade of water and logs downstream. To make the log drive as efficient as possible, logging companies would often clear the downstream channel of impediments. These efforts to improve the channel included the removal of boulders, large rocks, leaning trees, sunken logs, or any other obstructions or accumulations of woody debris. The effect of splash damming was a widening of the stream channel and scouring of stream sediments (Sedell et al. 1991). Figure 31 shows sites identified by Miller (2010) where splash dams were constructed, as well as stream segments that were subjected to log drives in the OC Chinook salmon ESU. Legacy effects from these activities are still impacting stream complexity (Stout et al. 2012). These activities have contributed to loss of wood or boulders that acted to hold back gravel in the channel, loss of large trees that act as key constituents of log jams, and incision of stream channels and loss of floodplain connectivity (Stout et al. 2012).

Figure 31. Historic splash dams and log drives in the OC Chinook salmon ESU (Miller 2010).

Another historic activity that continues to have a legacy effect on stream complexity was the practice of stream clearing and cleaning. State and federal agencies undertook major efforts to remove debris jams believed to be blocking fish passage, and forest practice rules required the removal of slash (limbs and tops) from streams after timber harvest (Hicks et al. 1991, Stout et al. 2012). Debris removal can cause a decline in channel stability, a reduction in the quality and quantity of pool habitat, and an increased frequency of riffle habitat (Hicks et al. 1991). These efforts to "clean" the stream channel for fish passage began in the 1940s and continued through the 1970s (Reeves et al. 1991).

Fish passage barriers

There have been reductions in connectivity and access to historical estuarine and freshwater salmon habitats resulting from two primary sources: 1) fish passage blocked or partially blocked by culverts, tide gates, bridges, dams, dikes, and levees, and 2) the loss of estuarine and tidal habitats. The Oregon Fish Passage Barrier Data Standard (OFPBDS) dataset contains a list of fish passage barriers affecting fish migration throughout the state of Oregon (ODFW 2019b). The types of barriers documented in the dataset and within the range of OC Chinook salmon consist of bridges, culverts, dams, fords, tide gates, and weirs/sills, as well as other unknown or undescribed barriers. The OFPBDS dataset does not include structures that are not associated with instream features (such as dikes, levees, or berms).

The OFPBDS dataset is the most comprehensive compilation of fish passage barrier information in Oregon; however, it does not represent a complete and current record of every fish passage barrier within the state. Within the range of the OC Chinook salmon ESU, the fish passage dataset includes several thousand barriers that are considered to block fish passage completely or partially, or for which the status of passage is unknown.

Due to the number of barriers and the associated cost of repairing them, only a small proportion receive attention each year. ODFW has prioritized a list of barriers to identify those most important to fix to allow migratory fish to access critical habitats. Scoring criteria are calculated to estimate the amount of habitat gained for purposes of prioritizing artificial obstructions at which fish passage would benefit native migratory fish in the state of Oregon. The prioritized list includes 26 barriers that effect OC Chinook salmon (Table 20).

Within the Tillamook and Nestucca River subbasins, local organizations have partnered to address fish passage barriers. The Salmon SuperHwy project is an effort to restore access for fish to almost 180 miles of blocked habitat throughout six salmon and steelhead rivers of Oregon's North Coast.[4] Approximately half of the identified barriers still need to be fixed over the next five years to achieve identified population viability goals (NMFS 2022a).

Another factor that has affected habitat access and availability is the construction of levees and dikes to protect land from floods or tides. Levees and dikes can block fish access to tidal stream, marsh, and swamp habitat in estuarine and freshwater tidal areas. The Oregon Department of Geology and Mineral Industries compiled pre-existing data on levees

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[4] https://www.salmonsuperhwy.org/

Table 20. ODFW (2019) Fish Passage Barriers Priority List for barriers effecting OC Chinook salmon. Passage levels: 5 = barrier to all native migratory fish, 4 = barrier to some native migratory fish adults and/or species, 3 = barrier to some native migratory fish adults and/or species for only part of migration period, 2 = barrier to all native migratory fish juveniles, 1 = barrier to some native migratory fish juveniles and/or for only part of migration period.

Sub-basin	Stream name	Barrier name	Species in need of passage at barrier	Passage level
Nehalem	Rock Creek	Swimming Hole Dam	Summer Chinook salmon, coho salmon, winter steelhead, cutthroat trout, Pacific lamprey	3
	Fishhawk Creek	Fishhawk Creek Dam	Summer Chinook salmon, coho salmon, winter steelhead, cutthroat trout, Pacific lamprey	3
	Gallagher Slough	Unnamed tidegate	Fall and summer Chinook salmon, coho salmon, chum salmon, cutthroat trout	4
Wilson–Trask–Nestucca	Three Rivers	Cedar Creek Hatchery Weir	Fall and spring Chinook salmon, coho salmon, winter and summer steelhead, cutthroat trout, Pacific lamprey	4
	Upton Slough	Upton Creek tidegate	Chinook salmon, coho salmon, chum salmon, steelhead, cutthroat trout, Pacific lamprey	2
	Gold Creek	Trask Hatchery barrier (rack)	Fall Chinook salmon, coho salmon, winter steelhead, cutthroat trout, Pacific lamprey	5
	South Fork Wilson River	Tuffy Dam	Fall and spring Chinook salmon, coho salmon, winter and summer steelhead, coastal cutthroat trout, Pacific lamprey	2
	Unnamed trib. to Catching Slough	Burton–Fraser Rd. tidegate	Chinook salmon, coho salmon, cutthroat trout, steelhead, Pacific lamprey	2
	Farmer Creek	Unknown	Fall Chinook salmon, coho salmon, chum salmon, winter steelhead, cutthroat trout, Pacific lamprey	3
	Mill Creek	Brickyard #2	Fall Chinook salmon, coho salmon, winter steelhead, cutthroat trout, Pacific lamprey	3
	Murphy Creek	Unnamed culvert	Fall Chinook salmon, coho salmon, chum, winter steelhead, cutthroat trout, Pacific lamprey	3
	Killam Creek	Unnamed culvert	Fall Chinook salmon, coho salmon, winter steelhead, cutthroat trout, Pacific lamprey	3
	Fox Creek	Culvert	Fall Chinook salmon, coho salmon, winter steelhead, cutthroat trout, Pacific lamprey	3
Siletz–Yaquina	North Creek	Unnamed culvert	Fall Chinook salmon, coho salmon, winter steelhead, cutthroat trout, Pacific lamprey	4
North Umpqua	North Umpqua River	Winchester Dam	Fall and spring Chinook salmon, coho salmon, summer and winter steelhead, cutthroat trout, Pacific lamprey, largescale sucker, Umpqua pikeminnow	3
South Umpqua	Cow Creek	Galesville Reservoir	Fall Chinook salmon, coho salmon, winter steelhead, cutthroat trout, Pacific lamprey, largescale sucker, Umpqua pikeminnow	5
	Camp Creek	Unnamed barrier	Fall Chinook salmon, coho salmon, winter steelhead, cutthroat trout, Pacific lamprey	4
	Canyon Creek	Canyon Creek Dam	Fall Chinook salmon, coho salmon, winter steelhead, cutthroat trout, Pacific lamprey	3
	Russell Creek	Unnamed barrier	Fall Chinook salmon, coho salmon, winter steelhead, cutthroat trout	3
Coos	Williams River	Williams River Quarry Falls	Fall Chinook salmon, coho salmon, winter steelhead, Pacific lamprey	4
	Big Creek	Unknown	Fall Chinook salmon, coho salmon, winter steelhead	4
Coquille	Baker Creek	Baker Creek Culvert	Fall Chinook salmon, coho salmon, winter steelhead, cutthroat trout, Pacific lamprey	4

and levee-like features in a geospatial inventory (Table 21; DOGAMI 2017). Within the OC Chinook salmon ESU, nearly 400 dikes have been either removed or breached. But 872 dikes and natural levees with man-made enhancements continue to limit access to potential salmonid habitat (Figure 32). The OFPBDS dataset indicates that there are approximately 320 tidegates in the OC Chinook salmon ESU, the vast majority of which are not likely to provide fish passage. NMFS's five-year review for OC coho salmon (NMFS 2022) emphasizes the need to address the lack of fish passage and access to estuarine habitat in the Nehalem, Tillamook, Yaquina, Alsea, Siuslaw, Umpqua, Coquille, and Coos River sub-basins.

Table 21. Summary of levee features identified within the OC Chinook salmon ESU in the Statewide Levee Database for Oregon (DOGAMI 2017).

	Feature type							
Sub-basin	**Breached dike**	**Historical/ removed dike**	**Man-made dike**	**Natural levee**	**Natural levee with man-made enhance-ments**	**Riprap**	**Sidecast of signifi-cance**	**Totals**
Necanicum	7	1	16		2		3	29
Nehalem	21	2	21	20	9	5	12	90
Wilson-Trask-Nestucca	51	23	149	24	38	15	59	359
Siletz-Yaquina	76	10	61	20	38	10	46	261
Alsea	23	15	39	3	3	10	21	114
Siuslaw	20	3	50	10	16	10	16	125
Siltcoos							2	2
Umpqua	15	3	73	20	23	6	28	168
Coos	95	13	197	24	22	46	88	485
Coquille	2	4	61	22	44	17	93	243
Sixes			11		4	11	15	41
Totals	**310**	**74**	**673**	**143**	**199**	**130**	**383**	**1,912**

Dams and diversions

Dams affect the way water and sediment move down a river, changing the amount and timing of flow, the size of substrates downstream of the dam, and the temperature and chemical characteristics. And because dams transform the upstream habitat from a river into a lake, they change the amount and location of available habitat and significantly alter salmonid interactions with predators and competitors. Dams can also act as barriers to juvenile salmon migrating to the ocean, and as obstacles to adult fish returning to their natal streams to spawn.

Dams of various sizes are found in nearly every Oregon coastal sub-basin. It is unclear how many of these dams are directly or indirectly effecting OC Chinook salmon. However, as noted above, ODFW maintains a priority list of barriers that block access to native migratory fish. There are two dams in the Nehalem River basin, two in the Wilson–Trask–Nestucca basin, and three in the Umpqua River basin that have been identified as priorities for OC Chinook salmon (Table 20).

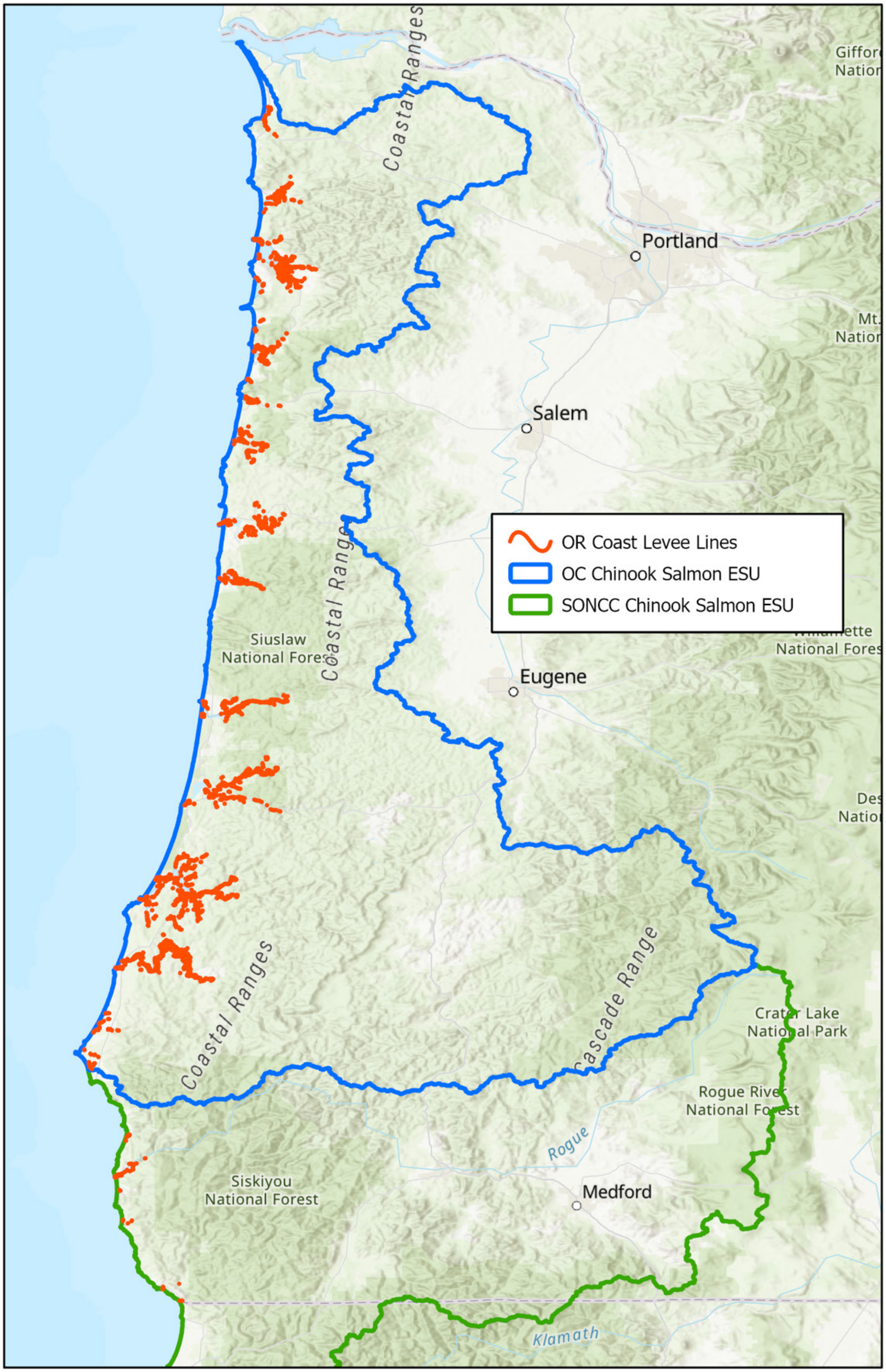

Figure 32. Levee lines from the Statewide Levee Database (DOGAMI 2017).

Vernonia, Oregon, has a dam located on Rock Creek in the upper Nehalem River basin. During the summer months, the City of Vernonia dams Rock Creek in Hawkins Park to create a public swimming hole, and to fill a permanent kiddie pool. Fishhawk Creek Dam in the Nehalem River sub-basin is located near Birkenfeld, Oregon. The dam was constructed in 1967 and currently does not meet ODFW criteria for upstream and downstream fish passage. We could find very little information about the two dams on the priority list for the Wilson–Trask–Nestucca sub-basin. Tuffy Dam is located on the South Fork Wilson River and the other dam is an unnamed dam on Farmer Creek.

The priority dams in the Umpqua River basin are Winchester Dam, Galesville Reservoir Dam, and Canyon Creek Dam. Winchester Dam is an approximately 450-foot-long and 17-foot-high concrete, steel, and wood structure that spans the channel of the North Umpqua River at Winchester, Oregon. Constructed in 1890, the dam was added to the National Register of Historic Places in 1996. The dam's hydropower facilities have long since been removed, and the structure is now maintained solely for the recreational benefit of the Winchester Water Control District. Winchester Dam has been on ODFW's statewide fish passage priority list since 2013 (ODFW 2019). Although the dam has a fish ladder, ODFW considers the dam and fish ladder to impede access to 160 miles of high-quality habitat for Chinook salmon.

Galesville Reservoir is a water storage reservoir in the Klamath Mountains of Douglas County, Oregon. The dam was completed in October 1986. The dam does not include a fish ladder, so it acts as a complete fish passage barrier. The other priority dam in the Umpqua River basin is on Canyon Creek and is partially passable.

Withdrawing water from streams can lead to reduced water availability, reduced connectivity of streams, increased stream temperatures, and a reduction in growth and survival of salmonids. Water withdrawals and, more specifically, instream flows are a problem in the Middle Umpqua, South Umpqua, Coos, Coquille, Floras, and Sixes River sub-basins (NMFS 2016b).

Habitat trends

In 1997, Oregon's governor and its legislature adopted the Oregon Plan for Salmon and Watersheds (Oregon Plan) "to restore Oregon's native fish populations and the aquatic systems that support them to productive and sustainable levels that will provide substantial environmental, cultural, and economic benefits" (ODFW 2014a, p. 85). The Oregon Plan organized conservation actions and monitoring, and focused investments in habitat protection and enhancement to address declines in fish populations and watershed health. As a component of the implementation of the Oregon Plan, ODFW has been monitoring instream habitat conditions across Western Oregon for over 20 years. The stream habitat surveys describe components and processes that contribute to the structure and productivity of salmonid populations. ODFW recently completed a 12-year review of the OC coho salmon conservation plan and included an evaluation of habitat trends.

ODFW (2021) evaluated trends for pool frequency, channel shade, fine sediments in riffle habitats, and wood volume at the reach scale (500–1,000-m survey lengths; Table 22). These four habitat attributes describe important indicators of sediment supply and quality, instream habitat complexity, and riparian forest community. The variables broadly represent habitat conditions, are well behaved statistically, and are responsive to management actions.

Table 22. Habitat variables evaluated in trend analysis, their relevance to rearing Chinook salmon, and desired trend directions (ODFW 2021).

Metric	Relevance to Chinook Salmon
Pool frequency (pools/100 m)	Pools are primary habitats for juvenile salmonids rearing in freshwater. Pool spacing depends on large woody debris loading and channel type, slope, and width. Having ample pool habitats throughout a reach ensures fish can distribute and not suffer density-dependent mortalities.
Channel shade (%)	Shading of stream channels helps cool streams, particularly in the summer. Riparian vegetation also provides nutrient inputs and prey for rearing fish and stabilizes the banks, reducing fine sedimentation.
Fine sediments in riffle habitat (%)	Riffle habitats are primary spawning habitats for adult salmon. Cold, clean gravel and cobble substrates provide suitable locations for redd formation and egg incubation. Fine sediment (silt, sand, and organics) in riffles can reduce egg survival by reducing oxygenation.
Wood volume (m^3/100 m)	Wood creates complexity in stream habitats and is a natural component of coastal streams. It can trap sediments, create pools, and provide nutrients and food for rearing fish. This metric reflects the presence of larger pieces or key pieces of wood.

ODFW (2021) summarized habitat trends by stratum (Table 23). The North Coast stratum includes the Necanicum, Nehalem, Tillamook, and Nestucca River basins. The Mid-Coast stratum includes the Salmon, Siletz, Yaquina, Alsea, and Siuslaw River basins. The Umpqua stratum includes the Lower, Middle, North, and South Umpqua River basins. The Mid-South Coast stratum includes the Coos, Coquille, Floras, and Sixes River basins.

Table 23. Trends in habitat metrics within the distribution of OC Chinook salmon, by stratum (ODFW 2021).

Stratum	Pool frequency (pools/100 m)	Channel shade (%)	Fine sediments in riffle habitat (%)	Wood volume (m^3/100 m)
North Coast	No trend	Positive trend	No trend	No trend
Mid-Coast	Positive trend	Positive trend	No trend	No trend
Umpqua	Positive trend	Positive trend	No trend	Positive trend
Mid-South Coast	Positive trend	Positive trend	No trend	No trend

Pool frequency and channel shade showed signs of improvement, but no trend was observed for fine sediments and wood volume (except for a positive trend in wood volume in the Umpqua River). Oregon Coast habitat conditions are influenced by legacy effects of past management actions, as well as current. The detection of positive trends and the lack of undesirable trends for some factors suggests progress in arresting further declines in habitat conditions, or that degradation in some areas is offset by improvements in others.

SONCC Chinook salmon ESU

From 1780 to 1840, trappers swept Oregon coastal rivers, including the Rogue River basin, reducing the robust beaver population to remnant levels (ODFW 2005b). Historically, beaver were so prevalent that the Takelma native people called the Applegate River valley "the beaver place" (BLM 1996a). Beaver were also historically much more prevalent in coastal streams in northern California, including the Smith and Klamath Rivers (Lanman et al. 2013). In the mid-to-late 1800s, extensive gold mining in the Rogue and Applegate River valleys and Smith and Klamath River basins resulted in major changes to salmonid habitat that are still evident today. In the 1850s, settlers began developing the flat alluvial valley bottoms and filling wetlands to increase agricultural productivity. Over a period of 150 years, these habitats were straightened and disconnected from their floodplains, wetlands and meanders were filled, beaver and their ponds were eliminated, flows were diverted, and riparian shade was reduced. The presence of beaver is important for creating and maintaining healthy salmon habitat, so the loss of substantial beaver populations is of concern (Lanman et al. 2013, Bouwes et al. 2016, Brazier et al. 2021, Jordan and Fairfax 2022).

The remoteness of the Rogue River basin delayed widespread forest harvest until railroad lines made it possible to export timber. Major changes in watersheds and streams associated with timber harvest occurred after World War II, when availability of heavy equipment and the high demand for wood led to extensive timber harvest in the Rogue River basin. Channel damage and erosion from a 1964 flood was widespread, exacerbated by timber harvest activities (including using stream channels for skidding logs) and road building activities (USFS and Flood Team 1998). Clear-cut timber harvest continued on public lands into the 1970s and 1980s and, although harvest technology improved, this activity resulted in another pulse of sediment that further degraded water quality and salmon habitat in downstream reaches (BLM 1996a, USFS 1999). USFS and BLM manage their lands with greater sensitivity to the needs of fish and wildlife since the adoption of the Northwest Forest Plan (USDA 1994).

Mining and gravel extraction

The discovery of gold in the Rogue River basin led to extensive hydraulic and dredge mining operations beginning in the mid-1800s. Currently, mining within the SONCC Chinook salmon ESU is primarily in the form of instream gravel mining, placer mining, suction dredging, and upslope hardrock mining. The greatest threat from instream gravel mining is the alteration of channel morphology and hydraulic processes that alter the quantity and quality of instream habitat (e.g., pools and riffles; Kondolf 1994). The greatest threat from upslope mining is the increased potential for chemicals, sediment, or other types of contaminants to enter watercourses. Threats from placer mining and suction dredging include the rearrangement or destabilization of substrate and subsequent changes to macroinvertebrate assemblages (Kondolf and Wolman 1993).

Legacy effects from past gold mining may persist in some sections of the Rogue River basin, and there are still many active mining claims on federal lands. Gold mining on federal lands often occurs on low-gradient stream reaches that are located just upstream of private lands. These reaches are important habitat for juvenile salmonids as they represent some of the best low-gradient habitat available.

Gravel extraction has the potential to impact channel form, sediment delivery, and hydrologic functions in a river or stream (Brown et al. 1998). The severity of this threat primarily depends on the location of activity, the intensity, and the types of methods used. Instream gravel mining affects habitat primarily through the removal of gravel from the top of gravel bars by skimming. Lowered bars result in unstable riffles that scour redds, wider and shallower channels that present migration barriers, and simplified habitat with fewer pools for juvenile rearing and adult holding (Kondolf and Swanson 1993).

BLM (1996b) notes that gravel extraction is widespread in the vicinity of the I-5 corridor near Grants Pass, Oregon. The gravel operations adjacent to the mainstem Rogue River at the mouth of the Applegate River occupy what was likely a wetland complex and salmonid refugia before disturbance. The Applegate Watershed Council (Rogue Basin Coordinating Council 2006) expressed concern regarding gravel extraction because mainstem reaches are already depleted of coarse substrate due to Applegate Dam. One commercial operator removes approximately 500,000 cubic yards from the lower Applegate River annually, but much now comes from pits outside of the ordinary high-water mark (NMFS 2014). Gravel mining is a potential threat along the mainstem East Fork Illinois River. Pits excavated in the floodplain can trap juvenile and adult salmon during high-flow events. Most of these stranded fish perish if no outlet is available when flows recede.

Mining activities within the Klamath and Smith River basins began prior to 1900. The negative impacts of stream sedimentation on fish abundance were observed as early as the 1930s. Mining operations adversely affected spawning gravels, decreased survival of fish eggs and juveniles, decreased benthic invertebrate abundance, increased adverse effects to water quality, and impacted stream banks and channels. Gravel mining has also removed coarse sediment, which can significantly alter physical habitat characteristics and fluvial mechanisms, such as causing increased river depth, bank erosion, and head-cutting (Freedman et al. 2013). Since the 1970s, however, large-scale commercial mining operations have been eliminated in California due to stricter environmental regulations, and in 2009 California suspended all instream mining using suction dredges. The use of vacuum or suction dredge equipment, otherwise known as suction dredging, was reaffirmed as prohibited in 2016 via California Senate Bill (SB) 637,[5] and remains prohibited and unlawful throughout California (see California Fish and Game Code §5653, 5653.1, 12000(a)[6]).

Timber harvest

Substantial timber harvest has occurred throughout the SONCC Chinook salmon ESU. In many of the basins, while timber harvest activity has decreased since the peak over 50 years ago, and practices and management have improved, the effects of past timber harvest practices continue and future timber harvest (particularly on private lands) may pose a threat to Chinook salmon. In many streams, timber harvest in the riparian areas has resulted in reduced inputs of leaf litter, terrestrial insects, and large wood (Reeves et al. 1993, Nakamoto 1998). Reduction of large wood from the harvest of streamside timber has resulted in the reduction of cover and shelter from turbulent high flows (Cederholm et al. 1997). Numerous studies have identified impacts,

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[5] https://wildlife.ca.gov/Licensing/Suction-Dredge-Permits; visited 12 May 2023.

[6] https://leginfo.legislature.ca.gov/faces/codesTOCSelected.xhtml?tocCode=FGC&tocTitle=+Fish+and+Game+Code+-+FGC

including reduced large woody debris, increased water temperature, and increased erosion and sedimentation. These impacts have been shown to impair the reproductive success of salmon due to increased turbidity, loss of interstitial spaces for use by juveniles, the smothering of eggs by fine sediments, loss of deep pools, and blockage of spawning habitat by landslides (Brown and Krygier 1971, Beschta 1978, Beschta and Taylor 1988).

One of the greatest continuing stresses from timber harvest is the residual effects of increased input of fine sediment into streams. This impact does not cease when timber harvest activities are complete, but instead continues a legacy of negative effects that begin anew during each winter storm event or high flow. Road building and other timber harvest activities have resulted in mass wasting and surface erosion that will continue to elevate the level of fine sediments in spawning gravels and fill the substrate interstices inhabited by invertebrates (Platts et al. 1989, Suttle et al. 2004). Changes in channel morphology will continue to alter the hydrology and timing of flows in areas affected by these chronic events. Bisson et al. (1997) estimated that, due to anthropogenic activities such as timber harvest, the frequency of major floods was two-to-ten times greater, debris flows and dam-break floods were five-to-ten times more frequent, and slumps and earth flows were two-to-ten times more frequent than natural background conditions. This increase in catastrophic events will likely continue to dramatically alter the conditions in which Chinook salmon spawn and rear, causing reductions in food supply, reduced quality of spawning gravels, and increased severity of peak flows during heavy precipitation. Additionally, the continued removal of riparian canopy cover from these events will result in increased solar radiation, which will further increase water temperature (Spence et al. 1996).

The threat from future timber harvest will depend partly on the state's forest practices and the forest practices for federal lands. This topic is explored in Risk Factor 4.

Dams and diversions

The Rogue River basin contains two dams operated by the U.S. Army Corps of Engineers (USACE). William Jess Dam (also known as Lost Creek Dam) was completed in 1977, Applegate Dam in 1979. The William Jess Dam allows for fish passage, but the Applegate Dam does not.

Storage accrued during the filling of the reservoirs is dedicated to specified purposes, including habitat enhancement for Chinook salmon. When Lost Creek Lake fills, 180,000 acre-feet of storage are released to meet downstream purposes, including the release of 125,000 acre-feet for fish enhancement purposes. When Applegate Lake fills, 66,000 acre-feet of storage are subsequently released to meet downstream purposes, including the release of 40,000 acre-feet for fish enhancement purposes. Any dedicated storage that is not purchased for consumptive use is also available for downstream enhancement of fish resources (ODFW 2013).

USACE releases reservoir storage from the reservoirs for multiple fish purposes, one of which is to increase the amount of habitat for juvenile salmonids rearing in downstream areas. This operational strategy has successfully enhanced habitat for juvenile Chinook salmon in the Rogue River, as evidenced by the increase in flow during the summer rearing period (ODFW 2007b). USACE operation of Applegate Dam affects flow in the Applegate River during autumn to aid the upstream migration of adult Chinook salmon. The operational strategy has been successful in increasing the available spawning habitat and distribution of fall-run Chinook salmon in the Applegate River (ODFW 2013).

ODFW (Thompson and Fortune 1970) conducted widespread surveys of the Rogue River basin to assess water flow and its effect on fish habitat and carrying capacity for salmonids. The study was designed to inform the Oregon Water Resources Board so that a "beneficial water use program" could be developed. Thompson and Fortune (1970) contain comprehensive flow tables for all major salmon-producing tributaries in the Rogue River basin, including recommended minimum flows. It also provides a summary of the Rogue River basin fish community, including the Middle Rogue and Applegate Rivers. The report identified flow depletion as a major cause of stress, disease, and predation to Pacific salmonids.

In addition to the two USACE dams described above, there are numerous other dams and diversions in the Rogue River basin that limit upstream and downstream habitat access for adult and juvenile Chinook salmon. As part of its fish screening and passage program, ODFW maintains a statewide fish passage priority list. In 2019, ODFW identified 35 dams and diversions in the Rogue River basin that do not allow sufficient fish passage for Chinook salmon (Table 24).

Table 24. Dams and diversions in ODFW's fish passage priority list for the Rogue River basin (ODFW 2019). Passage levels: 3 = barrier to some native migratory fish adults and/or species for only part of migration period, 2 = barrier to all native migratory fish juveniles, 1 = barrier to some native migratory fish juveniles and/or for only part of migration period.

Sub-basin	Stream name	Barrier name	Species in need of passage at barrier	Passage level
Applegate	Applegate R.	Murphy Dam	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	3
	Applegate R.	McKee Diversion Dam	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	3
	Applegate R.	Bridgepoint diversion push-up dam	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	1
	Applegate R.	Taylor diversion push-up dam	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	1
	Applegate R.	New Berryman push-up dam	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	1
	Slate Cr.	Lovelace Dam	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	3
	Slate Cr.	Santilla Fish Farm Dam (Harboldt)	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	3
	Waters Cr.	Miller Dam	Fall Chinook salmon, coho salmon, summer and winter steelhead, cutthroat trout	3
	Williams Cr.	Williams Creek Boulder push-up dam	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	3
	Williams Cr.	Watts–Topin diversion	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	3

Sub-basin	Stream name	Barrier name	Species in need of passage at barrier	Passage level
Illinois	Althouse Cr.	Floyd Ditch push-up dam	Fall Chinook salmon, coho salmon, Pacific lamprey, winter steelhead, cutthroat trout	3
	Althouse Cr.	Upper Spences push-up dam	Fall Chinook salmon, coho salmon, Pacific lamprey, winter steelhead, cutthroat trout	3
	Althouse Cr.	Houck–George Ditch push-up dam	Fall Chinook salmon, coho salmon, Pacific lamprey, winter steelhead, cutthroat trout	3
	Althouse Cr.	Morrey Ditch push-up dam	Fall Chinook salmon, coho salmon, Pacific lamprey, winter steelhead, cutthroat trout	3
	Rough & Ready Cr.	Seats Dam	Fall Chinook salmon, coho salmon, Pacific lamprey, winter steelhead, suckers, cutthroat trout	3
	Sucker Cr.	Lewis–McCann push-up dam	Fall Chinook salmon, coho salmon, Pacific lamprey, winter steelhead, suckers, cutthroat trout	1
	Sucker Cr.	White–Brown push-up dam	Fall Chinook salmon, coho salmon, Pacific lamprey, winter steelhead, suckers, cutthroat trout	1
	Sucker Cr.	Holland push-up dam	Fall Chinook salmon, coho salmon, Pacific lamprey, winter steelhead, suckers, cutthroat trout	1
	Sucker Cr.	Seyferth District push-up dam	Fall Chinook salmon, coho salmon, Pacific lamprey, winter steelhead, suckers, cutthroat trout	1
	West Fork Illinois R.	O'Brien push-up dam	Fall Chinook salmon, coho salmon, Pacific lamprey, winter steelhead, suckers, cutthroat trout	3
	Wood Cr.	Wood Creek Dam	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	3
Middle Rogue	Bear Cr.	Bear Creek diversion dam	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	3
	Bear Cr.	Medford Irrigation District, Bear Creek diversion	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	1
	Bear Cr.	Oak St. diversion	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	1
	Pleasant Cr.	Wakeman diversion dam	Fall Chinook salmon, coho salmon, summer and winter steelhead, cutthroat trout	3
Upper Rogue	E Fork Evans Cr.	Lower Alphonso Dam	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	3
	Evans Cr.	Williams–Whalen Dam	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	3
	Little Butte Cr.	Brown Ditch diversion	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	3
	Little Butte Cr.	Charley Dam	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	3
	Little Butte Cr.	Walcot Dam	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, suckers, cutthroat trout	1
	Little Butte Cr.	Little Butte Irrigation District	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, cutthroat trout	3
	N Fork Little Butte Cr.	Medford Irrigation District, N Fork Little Butte	Fall and spring Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, largescale sucker, cutthroat trout,	3
	N Fork Little Butte Cr.	Zundel Dam	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, cutthroat trout	3
	S Fork Big Butte Cr.	Eagle Point Irrigation District diversion dam	Spring Chinook salmon, coho salmon, summer and winter steelhead, suckers, cutthroat trout	3
	S Fork Little Butte Cr.	Medford Irrigation District, S Fork Little Butte	Fall Chinook salmon, coho salmon, Pacific lamprey, summer and winter steelhead, cutthroat trout	3

Although there are no large dams or major diversions in the Lower Klamath River, the large upstream water diversion and the existence of numerous large dams perpetuate impacts on the mainstem Klamath River. The five dams on the upper Klamath River create significant stresses in the river below (NMFS 2014). Low dissolved oxygen, elevated summer/fall water temperatures, and high nutrients are some of the water-quality issues exacerbated by the five mainstem dams. Poor water quality and changes in hydrology in the mainstem have been shown to affect disease incidence and mortality as well. On the positive side, the scheduled removal of four dams (Iron Gate, Copco 2, Copco 1, and J.C. Boyle) should substantially improve conditions in the lower river (NMFS 2021).

There are no large dams or major diversions in the Smith River basin. However, the fish hatchery facility at Rowdy Creek, a lower Smith River tributary, maintains a concrete apron that forms a weir to collect broodstock, and the diversion weir and concrete apron present passage issues for adult and juvenile salmonids even when the hatchery is not collecting fish (Hanson 2018). In addition, multiple small diversions for agricultural purposes exist in the lower Smith River basin.

Channelization and diking

Channelization and diking are especially prominent in the low-lying areas of most watersheds. Stream reaches have been channelized and diked to aid in the conversion of land from forest and riparian to agricultural, industrial, and urban land use. In nearly all the lowlands and estuaries within the ESU, the majority of historical floodplain and off-channel habitat has been diked for agriculture purposes and flood protection (NMFS 2014).

Diking leads to the direct loss of habitat through disconnection of channel, floodplain, and wetland habitat. The simplified channel disrupts normal hydrologic function, often increasing the velocity of the water and in turn displacing complex woody structures that provide important rearing habitat for juvenile salmon.

Levees and dikes have been constructed to protect residential or commercial property in the lower seven miles of the Rogue River, decreasing juvenile salmonid rearing habitat and disconnecting the river from its floodplain. Nearly all of the tidal wetlands in the Rogue River have been diked or channelized and are no longer available to salmonids. Development of the boat basin and marina along the south side of the river eliminated valuable tidal wetlands that provided off-channel habitat for salmonids. Channelization and confinement of mainstem and tributary reaches of the Illinois River are widespreaD.Channelization and diking are extensive across much of the Middle Rogue and Applegate River basins. Most of the habitat alteration is related to historical mining, agriculture, and urbanization (Prevost et al. 1997).

Nearly all of the tidal wetlands in the Chetco River have been channelized or diked and are no longer available to salmonids. Development along the south side of the river likely eliminated limited tidal wetlands that provided off-channel habitat for salmonid rearing and holding. Two marinas and a large jetty were built in the estuary, and most of the floodplain is developed. The estuary was partially filled when levees were constructed to improve navigability into the ocean. The mouth of the river and the mainstem upstream are now channelized and diked. The Chetco River channel above the North Fork has been confined in order to expand pastures for grazing.

Channelization and diking in the historical floodplain and estuary of the Smith River watershed are extensive and interfere directly with the ecological function in this area, decreasing rearing quality in the lower reaches of the basin. Although the historic extent of tidal wetlands is not known, it is likely that close to 7,000 acres of tidal wetlands have been converted to agricultural land (NMFS 2014). Remaining tidal channels are severely truncated and channelized, providing only a fraction of their potential as rearing habitat. The lower reaches of streams, such as Rowdy Creek, are also channelized, and important rearing habitat has been reduced and degraded.

Channelization and diking in the Lower Klamath River basin have resulted in loss of habitat in the estuary and along many important tributaries. Salt, High Prairie, Hunter, Mynot, Hoppaw, Waukell, Terwer, Saugep, Spruce, and Johnsons Creeks have all been impacted by these activities (Gale and Randolph 2000, Beesley and Fiori 2004, 2008). The lower two miles of Hoppaw Creek have been subjected to levee construction, channel realignment, and channelization for purposes of flood protection and Waukell Creek was realigned and channelized during the relocation of Highway 101 after the 1964 flood. A levee was constructed around the Klamath Glen housing community following the 1964 flood; this levee extends along the lower 0.5 miles of Terwer Creek, between its confluence with the Klamath River and the Highway 169 bridge crossing.

Agricultural practices

Agricultural impacts include draining, diking, or filling of wetland, estuary, and floodplain habitat, channelization and loss of stream complexity, riparian removal, reduced stream flow (associated with irrigation withdrawals) reduced stream bank stability and sedimentation, reduction of large woody debris recruitment, elevated water temperature, and water quality problems stemming from agricultural runoff (e.g., nutrients and pesticides). The most intensive agricultural land use coincides with broad alluvial valleys and the low-lying areas (often former floodplains) of most watersheds. Because of the land clearings, agricultural practices are partially responsible for the significant decrease in large woody recruitment in the lower basin.

Significant grazing occurs routinely on private lands and by permit on federally administered lands. Grazing may change soil infiltration rates, increase sedimentation, and can cause deleterious channel changes such as widening and shallowing of streams (Spence et al. 1996). Riparian vegetation alteration occurs with grazing as well, affecting wood recruitment, bank stability, and stream temperatures.

The life stages most affected by agricultural practices are juveniles and smolts, because they spend weeks to months rearing in the affected floodplain and estuarine areas and are particularly susceptible to water-quality contaminants and poor habitat quality.

Roads

High road densities, numerous road–stream crossings, and roads on steep slopes combine to pose a threat to salmonids in the Rogue River basin. Roads were built to support timber harvest, residential and urban development, and highway systems. An extensive network of small, unpaved roads exists in many of the upper sections of the Rogue River and its tributaries. Many of these roads run alongside streams and are known to yield chronic fine sediment and to pose elevated risk of catastrophic failure on steep slopes (USFS and Flood Team 1998). Road density in the basin averages 2–4 mi/mi^2, with much higher densities found in headwater tributaries. For example, BLM (1996c) found road densities in the urbanized lower Jumpoff Joe watershed to be 8.29 mi/mi^2, but 4.63 mi/mi^2 on BLM land. Upper Grave Creek has nearly 6 mi/mi^2 due to a combination of urban, rural residential, and timber management roads. Private forest lands, such as Cheney and Slate Creeks in the lower Applegate River sub-basin, have road densities of 4–5 mi/mi^2. The lower Big Butte Creek watershed (BLM 1996d) has approximately 4.6 miles of road per square mile of watershed.

The density of unpaved roads (>3 mi/mi^2) in the Lower Klamath River basin poses a threat to Chinook salmon. The highest densities of roads (>9.6 mi/mi^2) exist in Ah Pah, Surpur, and Waukell Creeks (Gale and Randolph 2000). Road decommissioning has been identified as a priority project to promote hydrologic restoration throughout the lower Klamath River basin (ESSA and Klamath Basin Working Groups 2023). Many streams have over 12 road crossings per square mile, and the South Fork Ah Pah watershed has over 25 road crossings per square mile (Gale and Randolph 2000). The cumulative sedimentation that has occurred over the past 50 years of road building and intensive timber harvest has caused significant impacts to stream habitat. Another major impact from roads is the impact that Highway 101, Highway 169, and rural roads have on estuary and tributary habitat in the Lower Klamath River. Highway 101 passes through or borders approximately three miles of estuary wetland habitat. In addition to the direct loss caused by the road footprint, the hydrologic connectivity of off-estuary wetlands located in the vicinity of the highway has been altered by the road and associated infrastructure, dikes, and levees along this route (Beesley and Fiori 2008). This altered hydrology affects estuarine function, especially during storms.

Similar high road densities can be found in several of the basins of the SONCC Chinook salmon ESU. Roads are considered a threat to salmon in the Smith River. Erosion on many abandoned or unmaintained roads is a chronic source of fine sediment input to many streams, and is exacerbated in the middle and upper parts of the basin by steep hillsides and an unstable geology. With a history of both agricultural use and timber harvest, the Smith River plain is characterized by high road density. Road surveys indicate that a majority of the watershed contains more than three miles of road per square mile, and the areas with the highest densities of roads (>3 mi/mi^2) include the Smith River plain, Rowdy Creek, Mill Creek, the South Fork, the lower North Fork, and scattered watersheds in the Upper Middle Fork.

Road–stream crossings and other barriers

There has been extensive reduction in connectivity and access to historical estuarine and freshwater salmon habitats resulting from two primary sources: 1) fish passage blocked or partially blocked by culverts, tide gates, bridges, dams, dikes, and levees, and 2) the loss of estuarine and tidal habitats. The OFPBDS dataset contains a representation of fish passage barriers affecting fish migration throughout the state of Oregon (ODFW 2019b). Barriers are structures which do, or potentially may, impede fish movement and migration. Barriers can be known to cause complete or partial blockage to fish passage, or they can be completely passable, or they may have an unknown passage status. The types of barriers documented in the dataset and within the range of SONCC Chinook salmon consist of bridges, culverts, dams, fords, tidegates, and weirs/sills, as well as other unknown or undescribed barriers. The OFPBDS dataset does not include structures which are not associated with instream features (such as dikes, levees, or berms). A summary of the dataset for the coastal Oregon basins in the SONCC Chinook salmon ESU is provided in Table 25.

The OFPBDS dataset is the most comprehensive compilation of fish passage barrier information in Oregon; however, it does not represent a complete and current record of every fish passage barrier within the state. Within the range of the SONCC Chinook salmon ESU, the fish passage dataset includes approximately 3,325 barriers that are considered to block fish passage completely, partially, or for which the status of passage is unknown.

Table 25. Summary of fish passage barrier data for the Oregon portion of the SONCC Chinook salmon ESU (ODFW 2019). *Unkn.* = unknown, *anad.* = anadromous, *maint.* = maintenance, *func.* = functions, *crit.* = critical.

		Status of fish passage at barrier					
Barrier type	**Fishway status**	**Blocked**	**Partial**	**Passable**	**Unknown anad.**	**Unknown**	**Total**
Bridge	None		1	31	1	447	480
Culvert	Needs maint.		1				1
	None	858	522	380	119	812	2,691
	Unkn.		2				2
Dam	Func. okay	1	11		4	2	18
	Needs maint.		11	1		1	13
	Needs maint., non-crit.		3				3
	None	21	227	10	17	13	288
	None, conflict		1			1	2
	None, exempt		2	4			6
	None, mitigation	2					2
	Unkn.	17	97	2	13	63	192
Ford	None		4		9	13	26
Other	None	2	8		3	2	15
	Unkn.		1		2		3
Tidegate	None		1				1
Unkn.	None		2				2
	Unkn.	1			2		3
Weir/Sill	Func. okay		1				1
	Needs maint.			1			1
	None		4				4
	Total	**902**	**899**	**429**	**170**	**1,354**	**3,754**

The high-threat scores for fish passage at culverts and stream crossings are a result of high road densities in urban areas, industrial timber lands, and rural residential areas of the Illinois, Middle Rogue–Applegate, and Smith River watersheds. Road–stream crossings barriers were rated as a high threat in the Smith River basin. According to the California Fish Passage Assessment Database (CDFW no date), there are 94 complete barriers, 79 partial barriers, 255 unassessed barriers, and several more features with unknown passage status in the Smith River basin.

Urban, residential, and industrial development

Grants Pass and Merlin (Oregon), the Applegate Valley, and Jumpoff Joe, Grave, Wolf, and Coyote Creek watersheds all contain high proportions of impervious habitat. Effects of urbanization increase with the total impervious area, causing increased peak flow, simplification of downstream channels, increased channel width to depth ratio, and toxic nonpoint-source pollution (Booth and Jackson 1997, Booth et al. 2002). In urban centers such as Grants Pass, industrial development may add to nonpoint-source pollution. Rural residential development is growing rapidly in Jackson County within the Middle Rogue–Applegate sub-basin, and septic system leakage or failure can lead to pollution. Backyard use of pesticides and fertilizers can also be significant in areas with concentrated development (Booth and Steinemann 2006). Residential development outside cities and towns often relies on surface water from streams or groundwater wells that may deplete nearby surface flows. Rural residential developments are specifically noted as a concern in Jumpoff Joe Creek (BLM 1996c), Little Applegate River (USFS 1995), and Star Gulch (BLM 1996a) in the Applegate sub-basin.

The city of Medford, Oregon, and surrounding areas have grown substantially over the last several decades; future projections suggest that Rogue Valley urban and rural development will continue to increase. Maps of impervious areas ( ) indicate extensive urbanization occurred in the Upper Rogue River sub-basin. For example, total impervious area (TIA) in the lower Bear Creek watershed is greater than 10%, a level which studies in other river systems found caused increased peak flows, decreased base flows, simplified channel conditions, increased nonpoint-source stormwater pollution, and resulted in loss of aquatic system function (Booth and Jackson 1997). An acute regional example of this phenomenon is that toxic stormwater runoff is leading to high pre-spawn mortality of adult coho salmon in tributaries to Washington's Puget Sound (e.g., Booth and Steinemann 2006, Peter et al. 2022). Urbanization and commercial development are expected to continue in the Interstate 5 corridor along Bear Creek.

Streams such as Big Butte and Little Butte Creeks supply water for urban areas and agriculture, and new residents add to growing water demand. Rural residential development also uses water and presents potential for pollution from septic systems.

The number of rural landowners in the Chetco River basin has increased considerably since 1950, when there were less than ten adjoining property owners near the mouth of the North Fork; in 2001, there were 92 (Massingill 2001). Human population growth is concentrated around Brookings Harbor at the mouth of the Chetco River and upstream to USFS ownership at the mouth of the South Fork Chetco River. As rural populations grow, so does the demand for water, the risks of increases in peak flow, increases in sediment inputs, riparian vegetation removal, increased bank protection, and water contamination. Currently, municipal uses account for most of the water withdrawals from the Chetco River and its tributaries (Massingill 2001).

Development continues to occur adjacent to the estuary, and fill material has reduced the size and function of the estuary. Marina development and other commercial activities in and near the estuary combine with urbanization to create a high amount of impervious area that can contribute to nonpoint-source pollution. Paved roads, parking lots, rooftops, or other surfaces that do not absorb rainfall tend to send much more water to streams, elevating peak flows and contributing pollution to streams (Booth and Jackson 1997). Leakage or percolation from rural residential septic systems is a potential source of nutrient pollution and increases the severity of summer algal blooms in the estuary.

Risk Factor 2: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Commercial, recreational, and tribal harvest

OC and SONCC Chinook salmon are harvested in tribal, commercial, and recreational fisheries in the ocean and fresh water. Harvest restrictions have been used for many decades to reduce impacts, and to increase the number of adults escaping to spawning grounds. However, because various Chinook salmon populations mix together, harvest can disproportionately impact less productive stocks. Harvest can also alter size, age structure, and migration timing for both smolts and adults. Finally, harvest can alter the structure of stream ecosystems by reducing the inputs of marine-derived nutrients from decaying Chinook salmon carcasses.

Harvest of OC Chinook salmon

The Pacific Salmon Treaty (PST) defines management structures for Chinook salmon fisheries under the treaty purview (inclusive of Chinook salmon ocean fisheries from Cape Falcon, Oregon, north to Alaska). The Pacific Salmon Commission (PSC) implements the PST and the PSC's Chinook Technical Committee (CTC) produces an annual fisheries model (CTC model) to manage Chinook salmon fisheries and stocks harvested within the treaty area. The CTC model is a large and complicated fisheries model, including a large number of Chinook salmon stocks originating from rivers in Oregon, Washington, British Columbia, and Alaska. Broadly, the CTC model integrates information from ocean catches, freshwater catches, spawning escapements, and recoveries of CWT fish from the treaty area to provide both pre-season forecasts and post-season estimates of stock-specific abundance and fisheries exploitation rates (CTC 2022a,b,c).

Fall-run Chinook salmon arising from the OC Chinook salmon ESU are represented as the two southernmost stock aggregates in the CTC model (North Oregon Coast and Mid-Oregon Coast groups). These groups are known as far north-migrating stocks and are caught in substantial numbers in mixed ocean stock fisheries in Alaska and British Columbia. The North Oregon Coast aggregate includes fall-run Chinook salmon spawning from the Necanicum River in the north through the Siuslaw Basin in the south, including the Nehalem, Tillamook, Nestucca, Salmon, Siletz, Alsea, and Yaquina River stocks. The Tillamook stock includes sub-stocks from the Kilchis, Miami, Trask, Tillamook, and Wilson Rivers. The Mid-Oregon Coast aggregate includes fall-run Chinook salmon from the Umpqua River in the north to the Elk River in the south, and also includes the Coos, Coquille, Floras, and Sixes River stocks. Note that spring-run Chinook salmon from the OC Chinook salmon ESU (most notably the Umpqua River) are not included in the CTC model and therefore do not have estimated exploitation rates.

For each aggregate, information is not available for all of the individual river runs, but each aggregate has a stock that serves as an indicator of fisheries exploitation—CWT Chinook salmon that are recovered in ocean and freshwater fisheries and at hatcheries or spawning grounds to determine the proportion fish harvests—and stocks that serve as escapement indicators. Escapement indicator stocks have annual freshwater surveys that provide estimates of Chinook salmon spawning abundance.

For the North Oregon aggregate, hatchery releases from the Salmon River serve as the exploitation indicator and Nehalem, Siletz, and Siuslaw are the escapement indicator stocks. For the Mid-Oregon aggregate, hatchery releases from the Elk River are the exploitation indicator and the South Umpqua and Coquille stocks are the escapement indicators. Cohort reconstruction techniques applied to tagged hatchery-origin fish are used to estimate the exploitation rate associated with reported catch from each fishery, as well as the total mortality rate which accounts for both the reported catch and incidental mortalities that occur in the fishery but are not observed in the catch (e.g., mortality from fish dropping off of hooks during fishing). Here we present only the estimates of total mortality data. All stocks within the North Oregon aggregate are assumed to have ocean mortality rates identical to the Salmon River exploitation indicator, and all Mid-Oregon aggregate stocks have ocean mortality rates identical to the Elk River exploitation indicator.

Temporal trends in fisheries exploitation

For OC stocks, we used output from the CTC Chinook salmon model to examine fisheries mortality from 1979–81 to the present for seven rivers (Figure 33). These plots show the proportion of adult-equivalent mortality estimated to have occurred as a result of all ocean fisheries, terminal fisheries (estuary and freshwater), and total fisheries morality (total is the sum of ocean and terminal exploitation rates). The CTC model uses adult-equivalent mortality (AEQ) to make mortality rates that occur at different times of the life cycle comparable. To provide intuition for the idea of adult-equivalency, imagine a single fishery that captures a three-year-old Chinook in year 2003 and then a five-year-old Chinook in year 2005. Both fish arise from the same cohort (both were born in 2000), but, between 2003 and 2005, some of the fish from the 2000 cohort died due to natural mortality, while others returned to their natal river to spawn; fish that die or spawn between 2003 and 2005 are unavailable to the fishery in 2005. Therefore, an age-5 fish caught in 2005 is equivalent to a larger number of younger fish that were present in 2003, and as a result, its AEQ is greater than that of the age-3 fish captured in 2003. The CTC model measures and reports mortality in AEQ units; the details of AEQ calculations are described in depth elsewhere (CTC 2022a).

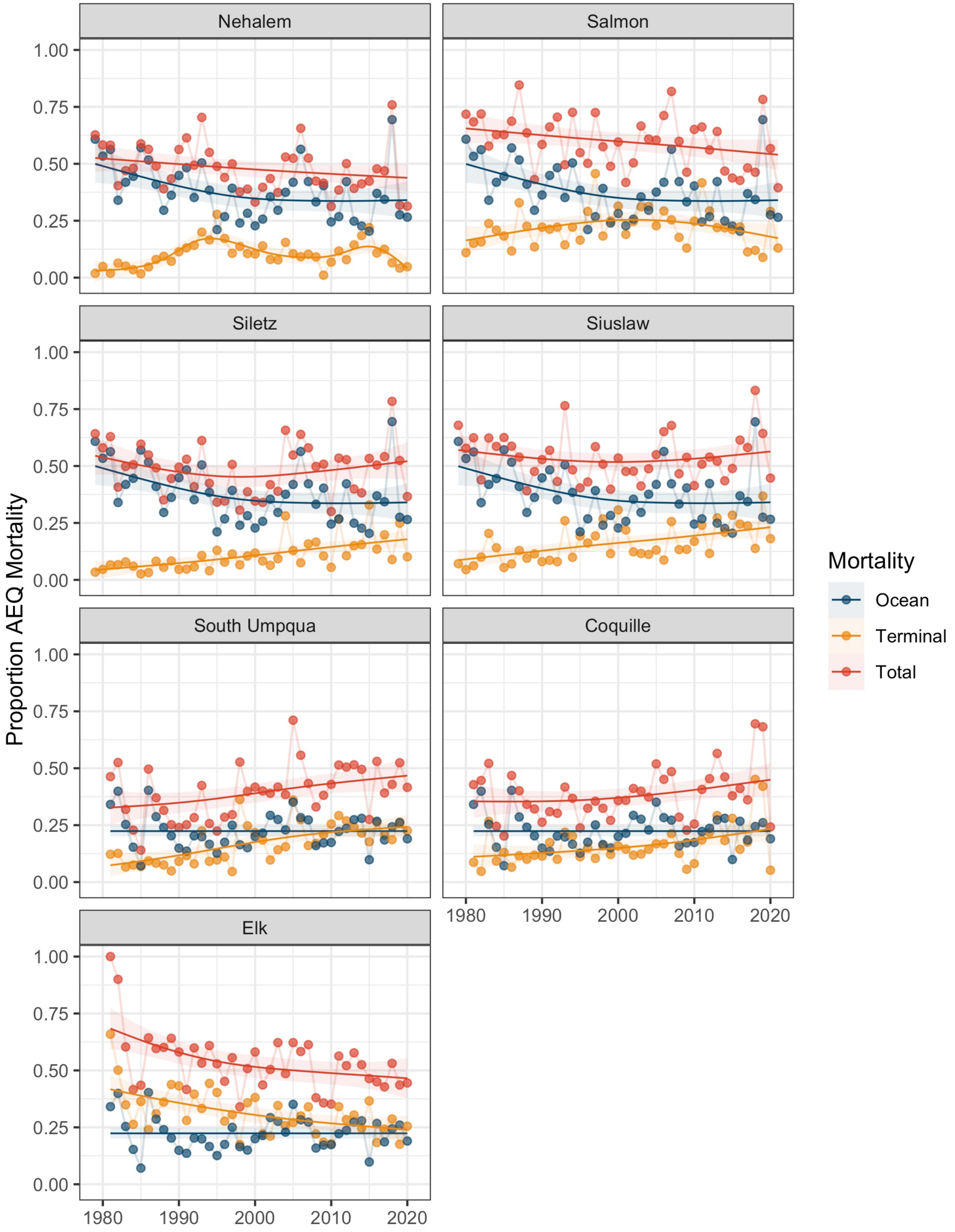

Figure 33. Estimated mortality associated with harvest in terms of adult-equivalents for ocean, terminal, and total (ocean + terminal) harvest for 7 OC rivers from the CTC model. Rivers are organized geographically (N to S). Note that the Nehalem, Salmon, Siletz, and Siuslaw Rivers share a single ocean mortality (corresponding to the North Oregon aggregate in the CTC model), and the South Umpqua, Coquille, and Elk Rivers share identical ocean mortality values (the Mid-Oregon aggregate). Trend lines are from a generalized additive smoothing model and are only for the purpose of aiding visualizing.

While AEQ is one way of expressing fisheries mortality, there are also other methods. For the Oregon Coast, ODFW reports harvest rates by river for terminal fisheries (bay and freshwater fisheries) as the proportion of total spawning run size harvested in terminal fisheries (Figure 34). Thus, the ODFW harvest rates do not account for mortalities in ocean fisheries, nor do they directly account for the age structure of the spawning fish. However, ODFW harvest rates are easier to interpret than AEQ mortalities, and are more easily comparable to quantities presented in some other salmon harvest models (e.g., the Klamath Ocean Harvest Model [KOHM]). Note that ODFW has monitored harvest of spring-run Chinook salmon in the Umpqua River from 2004–19 (Figure 34).

As both AEQ mortalities and freshwater harvest rates are available for some stocks, resulting in two descriptions of terminal harvest rates, it is important to recognize that these measures are not equivalent and not directly comparable. In general, terminal harvest rates from ODFW will provide higher proportions for freshwater harvest than the CTC model. Harvest rates show similar temporal patterns and are strongly positively related among rivers for which we have two terminal mortality estimates (Figure 35). The fact that these two measures of terminal harvest disagree does not indicate a problem, only that they are distinct means of measuring fisheries harvest.

Harvest of SONCC Chinook salmon

SONCC Chinook salmon are mainly encountered in ocean fisheries along the California and Oregon coasts south of Cape Falcon (Weitkamp 2010, Bellinger et al. 2015, Shelton et al. 2019), notably as prey for marine mammals. We construct the first coastwide state–space model for tagged fall Chinook salmon released from California to British Columbia between 1977 and 1990 to estimate seasonal ocean distribution along the west coast of North America. We incorporate recoveries from multiple ocean fisheries and allow for regional variation in fisheries vulnerability and maturation. We show that Chinook salmon ocean distribution depends strongly on region of origin and varies seasonally, while survival showed regionally varying temporal patterns. Simulations incorporating juvenile production data provide proportional stock composition in different ocean regions and the first coastwide projections of Chinook salmon aggregate abundance. Our model provides an extendable framework that can be applied to understand drivers of Chinook salmon biology (e.g., climate effects on ocean distribution). In discussing ocean harvest impacts for SONCC Chinook salmon, we will use three terms that represent slightly different things: 1) the exploitation rate (also referred to as the spawner reduction rate) represents the reduction in spawning escapement (from all fisheries combined[7]) relative to the escapement expected in the absence of fishing; 2) the age-specific ocean impact rate reflects all modeled ocean fishing mortality (landed and nonlanded [i.e., sublegal releases and drop-off mortality]) divided by an estimate of the ocean abundance for that age class at the start of the model year (1 September of the year prior to spawner return); and 3) the age-specific ocean harvest rate reflects only the part of the impact rate resulting from retained harvest.

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[7] The fisheries models used by the Pacific Fishery Management Council (PFMC) for Klamath River fall Chinook salmon do not account for mortality from bycatch in groundfish fisheries or other fisheries not directed at salmon, nor do they account for directed salmon fishing north of Cape Falcon.

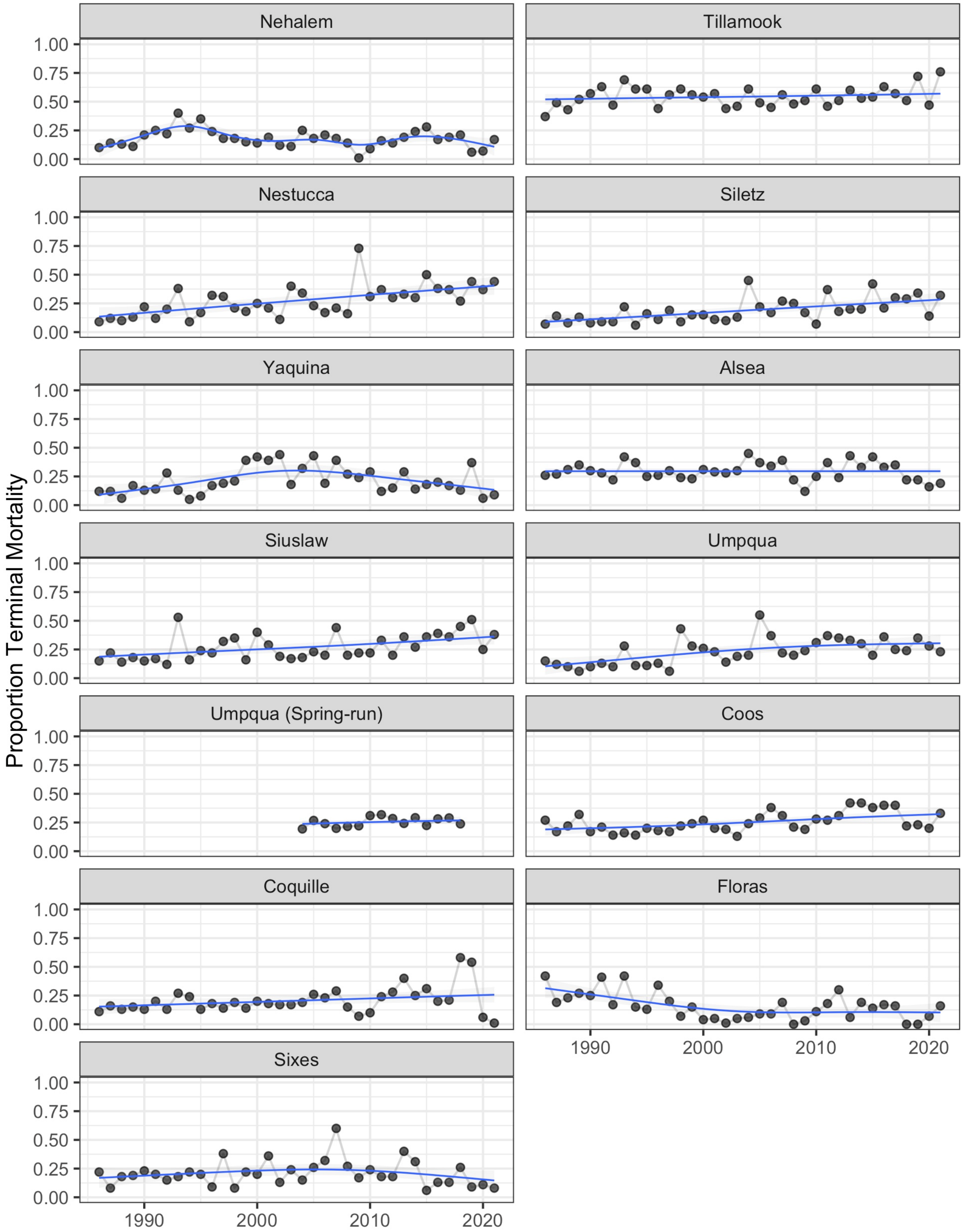

Figure 34. Estimated terminal area harvest morality in terms of proportion of terminal run size for Chinook salmon in Oregon Coast rivers. Mortality rates refer to fall-run fish unless otherwise noted. Rivers are organized geographically (N to S). Trend lines are from a generalized additive smoothing model and are only for the purpose of aiding visualizing.

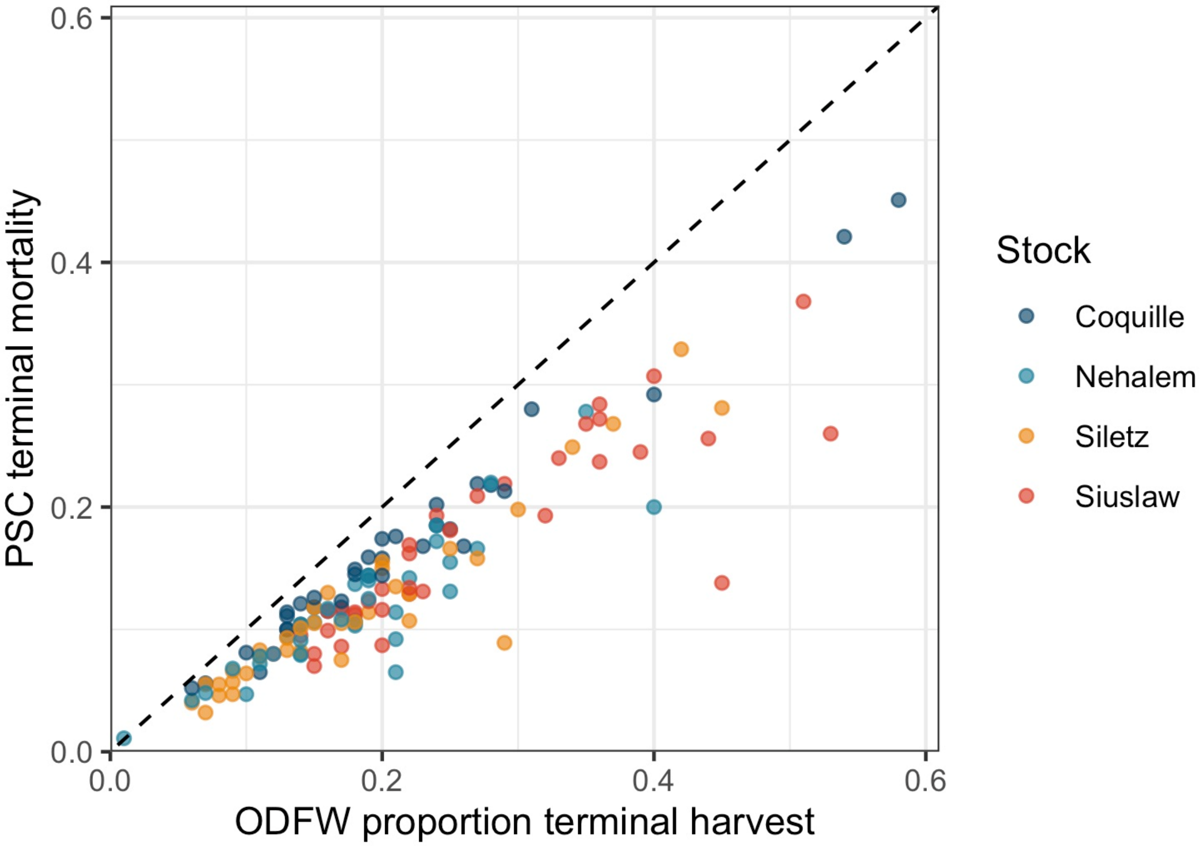

Figure 35. Comparing AEQ from the CTC model and terminal run mortality from ODFW in Oregon Coast rivers. Both estimates are only available for 4 rivers. Each point shows a mortality for a single year.

No direct estimates of ocean fishery impacts are made for any stock in the SONCC Chinook salmon ESU. Ocean fishery impacts on Klamath River fall Chinook salmon (KRFC) are estimated using cohort reconstruction techniques (Mohr 2006[8]) applied to tagged hatchery-origin fish, with the same age-specific ocean impact rates assumed to apply to natural-origin KRFC. PFMC assumes that the ocean harvest rate on KRFC is a reasonable proxy for SONCC stocks, based on broadly similar spatial patterns in CWT recoveries. We present harvest rates derived from the KOHM presented in PFMC's 2023 pre-season salmon report (PFMC 2023, their Table II-5). Harvest rates represent the fraction of the postseason estimate of ocean abundance harvested between 1 September (prior year) and 31 August (current year; Figure 36).

Terminal harvest rates are available for some fall- (2000–21, Figure 37) and spring-run (2004–18, Figure 38) stocks. For both, the terminal harvest fraction is the fraction of the total river run harvested by estuary and in-river fisheries; it does not account for ocean harvest rates.

According to ODFW (2023), terminal harvest rates are based on estimated harvest in bay and river fisheries and do not include mortality in ocean fisheries. Harvest estimates for 2000–18 are derived from combined angling tags returned to ODFW voluntarily by anglers (also referred to as punch card estimates); harvest estimates for 2019–21 are derived from angler harvest reporting in ODFW's Electronic Licensing System. Terminal harvest rates are based on escapement and harvest of wild and hatchery-origin Chinook salmon.

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[8] Mohr, M. 2006. Klamath River fall Chinook assessment: Overview. Unpublished report. National Marine Fisheries Service, Santa Cruz, California.

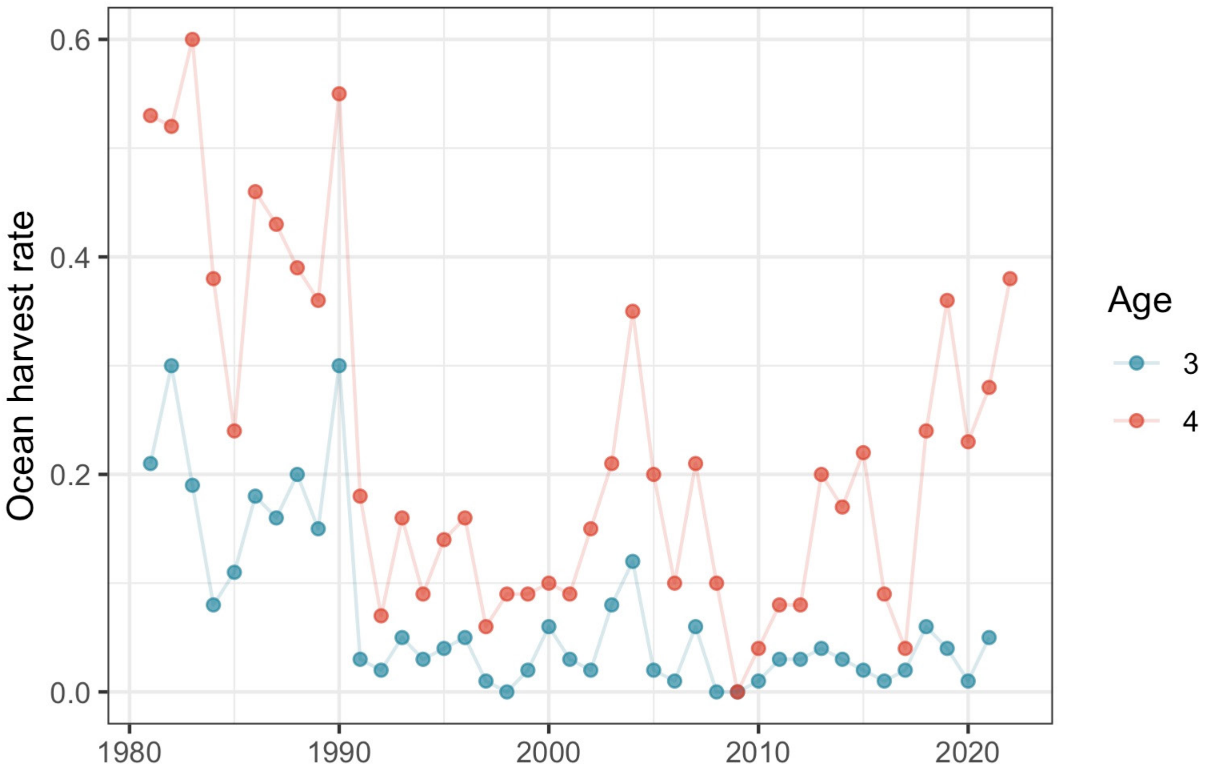

Figure 36. Ocean harvest rates for Klamath River fall Chinook salmon, the proxy for SONCC ocean harvest rates.

Estimated age-specific ocean and river harvest (PFMC 2023, their Tables II-3 and II-5) and exploitation rates (PFMC 2023, their Table V-4) for KRFC are reported each year. Estimates for harvest rates after age-4 are imprecise due to limited tag recoveries, but age-4 ocean harvest rates should reflect fully selected fishing mortality. For 2013–22, estimated age-4 ocean harvest rates on KRFC ranged from 0.04–0.38 (mean 0.22), with postseason estimates consistently exceeding preseason expectations (PFMC 2023, their Table II-5). Efforts are underway to address this model inaccuracy (PFMC 2022), but in 2022 the post-season age-4 ocean harvest rate of 0.38 was almost four times the preseason expectation of 0.10.

ODFW (C. Lorion, unpublished data) reports 2012–21 terminal harvest rates on Rogue River fall Chinook calmon of 0.04–0.28 with mean 0.12, and 2009–18 river harvest rates of Rogue River spring Chinook salmon of 0.01–0.14 with mean 0.08. Terminal harvest rate estimates can be higher on the Chetco (2012–21 range of 0.08–0.37 with mean 0.18) and Winchuck Rivers (0.00–0.36 with mean 0.09). Combining estimates of ocean and terminal harvest rates into exploitation rate estimates would require information on maturation schedules as well.

Scientific and educational utilization

The utilization (take) of OC and SONCC Chinook salmon for scientific and educational purposes in Oregon is monitored by ODFW and the California Department of Fish and Wildlife (CDFW). “Take” in this context is defined as activities that harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct. ODFW has been issuing scientific take permits for the take of fish, shellfish, and marine

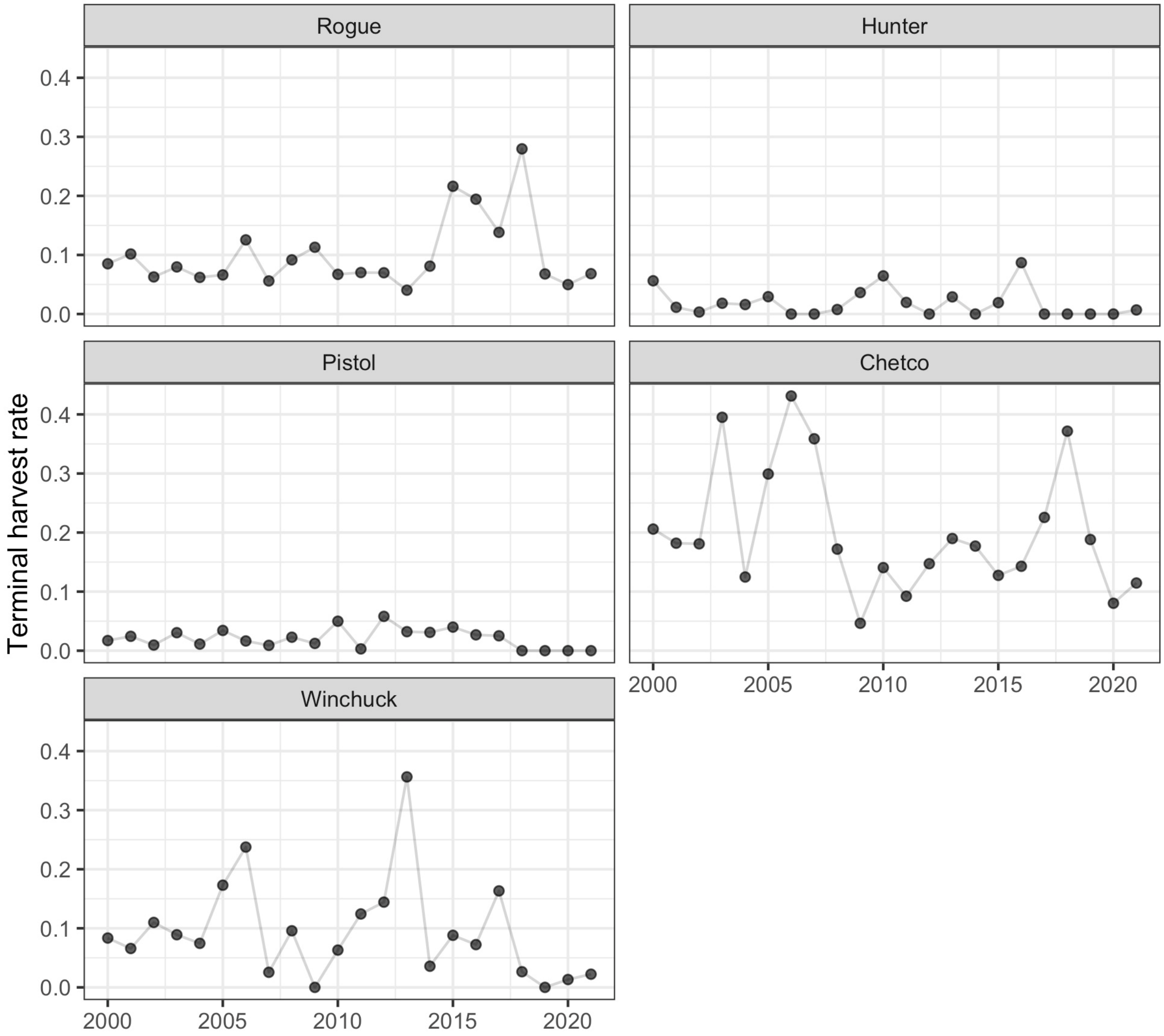

Figure 37. Terminal harvest rates for fall-run SONCC Chinook salmon. Terminal harvest rates are the fraction of the total river run size harvested in each river. Terminal harvest does not account for ocean harvest rates.

invertebrates through a permitting program since the early 1990s. ODFW's permits are good for one year, and the researcher must report actual take at the end of the year. For 2012–21, ODFW issued an average of 32 permits a year for take of OC Chinook salmon. The annual reported take averaged 5,296 for adult OC Chinook salmon, with zero reported mortalities. The annual reported take for juvenile OC Chinook salmon averaged 61,197, with 559 mortalities. The research permitted by ODFW has had only very small effects on the species' abundance and productivity, and no discernible effect on structure or diversity. ODFW employees are exempt from the state's permit requirements, and the take for research conducted by ODFW is not included in these totals. We do not have information on the amount of take occurring in ODFW's research projects.

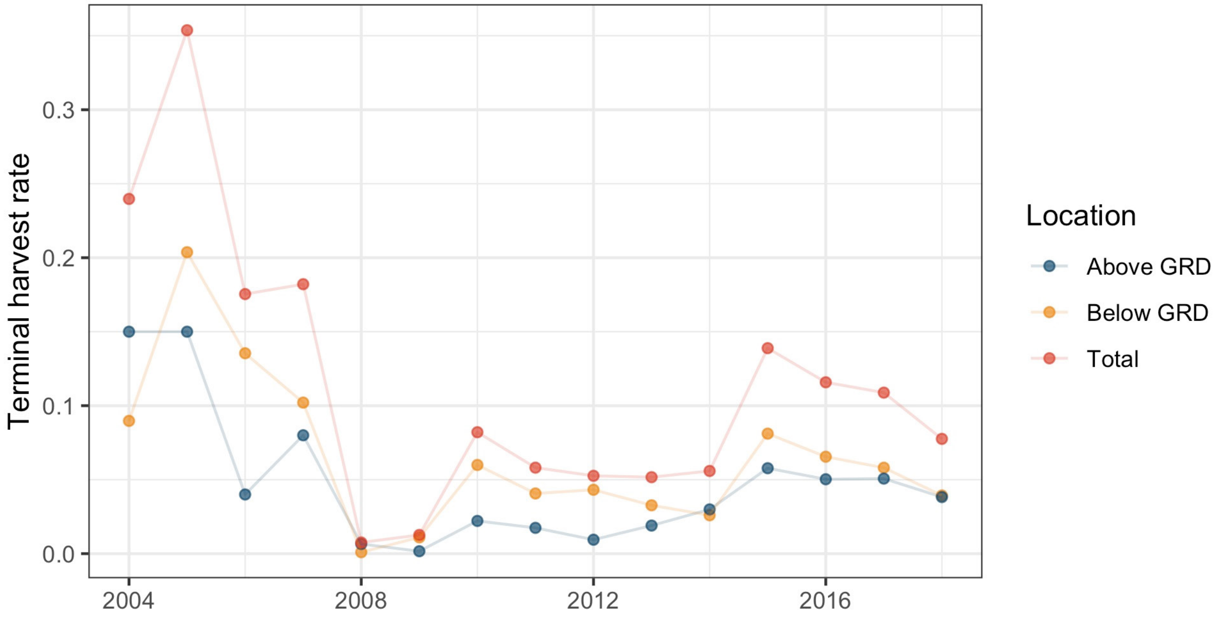

Figure 38. Terminal harvest rates for spring-run SONCC Chinook salmon in the Rogue River. Terminal harvest rates are the fraction of the total river run size harvested above and below Gold Ray Dam (GRD). Terminal harvest does not account for ocean harvest rates.

For the years 2012 through 2021, ODFW issued an average of five permits per year for take of SONCC Chinook salmon. Over that time period, the annual reported take in ODFW permits averaged 16 for adult SONCC Chinook salmon, with zero reported mortalities. The annual reported take for juvenile SONCC Chinook salmon averaged 36, with one mortality. The research permitted by ODFW has had very small effects on the species' abundance and productivity, and no discernible effect on structure or diversity. Once again, ODFW employees are exempt from the state's permit requirements, and the take for research conducted by ODFW is not included in these totals. We do not have information on the amount of take occurring in ODFW's research projects.

California Fish and Game Code (FGC) Sections 1002, 1002.5, and 1003 authorize CDFW to issue permits for the take or possession of wildlife—including mammals, birds and the nests and eggs thereof, reptiles, amphibians, fish, certain plants, and invertebrates—for scientific, educational, and propagation purposes. CDFW currently implements this authority through Section 650, Title 14, California Code of Regulations (CCR), by issuing scientific collecting permits (SCPs) to take or possess wildlife for such purposes. CDFW's SCPs are good for up to three years from the date of issuance, and researchers must report their take at the end of the year. CDFW issues several permits a year for research that may take SONCC Chinook salmon, and there are tens of permits active in any given year. Unfortunately, annual reported take is not maintained in an electronic database, and we were unable to determine the level of authorized take for scientific research of SONCC Chinook salmon in California.

Risk Factor 3: Disease or Predation

Disease

Infectious disease is one of many factors that influence adult and juvenile salmonid survival. Chinook salmon are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment. Specific diseases—such as amoebic gill disease (*Neoparamoeba perurans*), bacterial kidney disease (*Renibacterium salmoninarum*), bacterial cold water disease (*Flavobacterium psychrophilum*), enteronecrosis (*Ceratomyxa shasta*), columnaris (*Flavobacterium columnare*), furunculosis (*Aeromonas salmonicida*), ich (*Ichthyophthirius multifiliis*), infectious hematopoietic necrosis (infectious hematopoietic necrosis virus), trichodiniasis (*Trichodina* spp.), enteric redmouth disease (*Yersinia ruckeri*), black spot disease (caused by digenean trematodes in the families Diplostomatidae and Heterophyidae), and viral erythrocytic inclusion body syndrome (caused by an unclassified virus)—are known, among others, to affect Chinook salmon (Rucker et al. 1954, Wood and WDFW 1979, Wertheimer and Winton 1982, Leek 1987, Foott et al. 2007).

Naturally produced Chinook salmon may contract diseases that are spread through the water column (i.e., waterborne pathogens; Buchanan et al. 1983). Disease may also be contracted through interactions with infected hatchery fish (Fryer and Sanders 1981, Evelyn et al. 1984, 1985). A fish may be infected yet not show symptoms of the disease. Salmonids are typically infected with several pathogens during their life cycle. However, high infection levels (number of organisms per host) and stressful conditions (crowding in hatchery raceways, release from a hatchery into a riverine environment, high and low water temperatures, etc.) usually characterize the system before a disease state occurs in the fish.

Increased physiological stress and physical injury in migrating juvenile salmonids may increase their susceptibility to pathogens (Matthews et al. 1986, Maule et al. 1988). The presence of adequate water quantity and quality during late summer is a critical factor in controlling disease epidemics. As water quantity and quality diminish, and freshwater habitat becomes more degraded, many previously infected salmonid populations may experience large mortalities because added stress can trigger the onset of disease. These factors (common in various rivers and streams) may increase anadromous salmonid susceptibility and exposure to diseases (Holt et al. 1975, Wood and WDFW 1979).

OC Chinook Salmon ESU

Common diseases that affect Chinook salmon on the Oregon coast include amoebic gill disease, bacterial cold water disease, bacterial kidney disease, columnaris, furunculosis, ich, and trichodiniasis. Through regular monitoring conducted by state and federal agencies, we know that disease is a constant problem when artificially rearing fish in high densities (Saunders 1991). Rearing facilities expose captive fish to increased risk of carrying pathogens because of the stresses associated with simplified and crowded environments.

These diseases, amplified within the hatchery setting, contribute to the mortality of fish at all life stages and can travel rapidly to areas well beyond where effluent water is discharged. The outplanting of juvenile and adult fish can transfer disease upstream of the rearing site. There is also the potential for vertical transmission within eggs and possibly with adhesion of virus particles to sperm during fertilization (Meyers et al. 2019). Lastly, there is the potential for lateral infection through the travel of avian, mammalian, and other terrestrial predators which overlap with the distribution of artificially propagated fish.

The release of hatchery-produced Oregon coast Chinook salmon into the wild may also risk introducing pathogens and parasites to wild populations; this can result in temporary epidemics or permanent reductions in wild populations. These dynamics contribute to disease-driven mortality at all life stages in wild fish populations. In 2015, high water temperatures and repeated bouts of bacteria and parasite infections beginning in May killed over 150,000 summer steelhead in the Rock Creek Hatchery. According to ODFW, columnaris and ich are found in low levels in the North Umpqua River, which supplies water to the hatchery. When water temperatures rise, pathogen levels can increase rapidly, overwhelming a fish's natural defenses. Water temperatures in the North Umpqua River exceeded 71°F in July 2015, compared to previous years where highs were in the mid-60s.

ODFW (2014) identified population-level performance goals and the factors that may influence the realization of those goals. In the Oregon Coastal Conservation and Management Plan, limiting factors are defined as biological, physical, or chemical conditions altered to such an extent by anthropogenic (i.e., human-related) activities that they impede achievement of population biological performance goals. ODFW (2014) does not consider disease to be a limiting factor for OC Chinook salmon.

SONCC Chinook Salmon ESU

ODFW (2007a, 2013) considers disease to be a primary factor that affects the abundance of Chinook salmon in the Rogue River basin. Extensive mortalities of adult Chinook salmon were documented in the mainstem Rogue River in 1977, 1981, 1987, 1992, and 1994. Estimates of mortality rates during those years ranged between 28% and 70% of the spring-run Chinook salmon that entered the Rogue River (ODFW 2000). Columnaris was the disease most frequently identified in dead and dying fall-run Chinook salmon sampled in the Rogue River during the late 1970s and early 1980s (Amandi et al. 1982). Virulence of this bacterium varies among strains and epizootics may occur intermittently in salmonid populations (Becker and Fujihara 1978). Mortality rates of juvenile Chinook salmon infected with *F. columnare* increase as water temperature increases between 54°F and 70°F (Becker and Fujihara 1978). Summertime water temperatures in the Rogue River can approach the upper end of this range.

In the Rogue River basin, *F. columnare* has been detected in resident fish in Lost Creek Lake and in juvenile Chinook salmon held in the reservoir, but not in reservoir water or reservoir outflow (Amandi et al. 1982). Spring-run Chinook salmon in the Cole Rivers Hatchery were also found to be infected with the disease. *F. columnare* has also been found in several species of fish sampled throughout the Rogue River basin, including the Applegate River (Amandi et al. 1982). Other disease organisms detected in the Rogue River basin include *R. salmoninarum*, *C. shasta*, *A. salmonicida*, and infectious hematopoietic necrosis virus.

To minimize losses of adult and juvenile Chinook salmon to disease, ODFW identified targets for maximum water temperature at the U.S. Geological Survey (USGS) gage near Agness, Oregon (RMI 30), and requests releases of reservoir storage in order to meet water temperature targets in downstream areas. The reservoir water release strategy employed since 1995 is directed toward using reservoir storage to prevent, or to delay as long as possible, disease outbreaks. However, during an average year of water yield, the available amount of reservoir storage is insufficient to entirely prevent disease-related losses of spring- and fall-run adult and juvenile Chinook salmon (ODFW 2007b). Furthermore, as more reservoir storage is purchased for irrigation and municipal and industrial supply, the amount of storage available for fishery purposes will decrease.

The Klamath River has a history of myxosporean parasite infections, including *C. shasta* and *Parvicapsula minibicornis*, which can significantly impact survival among juvenile Chinook salmon. The California–Nevada Fish Health Center has performed standardized monitoring of myxosporean parasite infections in Klamath River juvenile Chinook salmon since 2009. The primary objectives of monitoring are to examine parasite prevalence and infection severity in juvenile Chinook salmon during the spring outmigration period, and compare parasite prevalence to previous years. Juvenile Klamath River Chinook salmon are assayed by quantitative polymerase chain reaction (QPCR) and histology for myxosporean parasite infection of *C. shasta* and *P. minibicornis*. The average *C. shasta* infection rate detected by QPCR was 49% and has ranged from as high as 91% to a low of 17% (2009–21). Prevalence of *C. shasta* infection by histology has averaged 26%, with a range of 3–75% over the same period of record. *P. minibicornis* infection prevalence by QPCR in juvenile Chinook salmon above the Trinity River confluence has averaged 86% (2009–21).

The reach of the Klamath River from the Shasta River to Seiad/Indian Creek is known to be a highly infectious zone for *C. shasta* and *P. minibicornis,* with high actinospores—especially from April through August (Beeman et al. 2008), although within and between years the size of the infectious zone and the magnitude of parasite densities may vary geographically (Voss et al. 2022). The highest rates of infection occur in the Klamath River within approximately 50 miles downstream of Iron Gate Dam (Stocking and Bartholomew 2007, Bartholomew and Foott 2010), and are less likely to occur downstream of the Trinity River confluence, within the SONCC Chinook salmon ESU.

In the fall of 2002, over 30,000 fall-run Chinook salmon died in the lower 30 miles of the Klamath River as a result of low water discharge, large run size, high water temperatures, and an epizootic outbreak of the bacterium *F. columnare* and the parasite *I. multifiliis* (Belchik 2015). Since that event, resource agencies and tribes have taken action to manage flows in the lower Klamath River to reduce risks of large-scale ich outbreaks among adult salmon (NMFS 2019a). The Yurok Tribal Fisheries Program (YTFP) initiated an effort in the lower Klamath River to generally monitor the health of migrating adult salmonids and to detect any ich outbreak before it reached lethal levels. From 2002 to 2014, YTFP monitoring observed moderate incidence of columnaris (18–40%) that was expected to have minimal sublethal effects, and almost no incidence of ich (Belchik 2015). However, in 2014, the YTFP monitoring program detected ich in migrating fish. Detections of ich numbers on gills of migrating salmon rose until they reached high levels (up to 67% severe infection); however, no mortality event was observed in the Klamath or Trinity Rivers, nor was a diseased state observed in these fish (Belchik 2015). The lack of disease despite high incidence of the parasite was posited to have been due to preventative emergency flow releases that occurred that year (Belchik 2015). In the spring of 2017, approaches to augment flows and reduce the likelihood and severity of any fish disease outbreak were formalized in a new Record of Decision for the Long-Term Plan to Protect Adult Salmon in the Lower Klamath River signed by the U.S. Bureau of Reclamation to fulfill its commitment to avoiding fish die-off in the lower Klamath River. One of the major components of the Bureau of Reclamation's operations plan is to maintain flows in the Klamath River to support coho salmon needs and to produce flows for disease mitigation or protection of coho salmon habitat during the spring/summer operation period. Because of similarities in run timing and juvenile rearing, we anticipate the actions to provide similar benefits for Chinook salmon in the Klamath River (NMFS 2019a).

Infection rates are influenced by water temperature and hydrology. Drought conditions and low river discharge likely contributed to the greater prevalence of infection (Voss et al. 2022). Because high water temperature is one of the primary drivers for disease infection rates, increased water temperatures associated with drought, climate change, and human activities (e.g., water diversions) are predicted to increase disease rates in the future (Woodson et al. 2011). As with adult salmon disease concerns, there have been additional efforts to reduce impacts of juvenile salmonid diseases, including implementation of flows to limit the abundance of disease-promoting algal blooms and polychaete host worm populations (NMFS 2019a). In laboratory tests, higher water velocity has been noted to result in greater polychaete densities but lower polychaete infection prevalence (Bjork and Bartholomew 2009). The higher water velocity decreased the infection severity in Chinook salmon.

Predation by marine mammals

Congress passed the Marine Mammal Protection Act (MMPA) in 1972 in response to increasing concerns among scientists and the public that significant declines in some species of marine mammals were being caused by human activities. The MMPA's protections have stopped the decline of many marine mammal populations and have led to the recovery of several in the northeastern Pacific Ocean, such as populations of harbor seals, Steller sea lions, and California sea lions. Although the diets of seals and sea lions are diverse and salmon may be a minor part of their diet, the overall increase in abundance of these species, as well as resident killer whales, may have implications for the long-term status of depleted, and in some cases ESA-listed, salmonid populations.

Pinnipeds (seals and sea lions) are known to prey on juvenile and adult salmon in both freshwater and marine environments. Riemer and Brown (1996) analyzed seal and sea lion food habits in the Columbia River, Oregon coastal rivers and estuaries, as well as nearshore and shoreline sea lion haul-out areas. Steller sea lion scat (fecal) samples were collected from the Rogue Reef and Orford Reef breeding sites, and salmonids were identified in 19.3% of samples. California sea lion samples were collected at the Cascade Head haul-out area near Lincoln City, Oregon, and salmonids occurred in 24.3% of samples in February and 7.9% in October.

Riemer et al. (2001) estimated the consumption of salmonids by pinnipeds in the Alsea and Rogue River basins (1997–99). Harbor seals were common in both basins, with as many as 200 animals in the Rogue River and 700 in the Alsea. California sea lions and Steller sea lions were common in the Rogue, but rare in the Alsea. Scat samples were collected at harbor seal haul-out areas within both rivers. Although both sea lion species commonly occurred in the lower Rogue River, and California sea lions were occasionally observed in Alsea Bay, sea lions did not haul out at any location in either study area.

In scat samples collected from harbor seals in the Alsea River, the frequency of occurrence of salmonids was estimated to range from 4.3–7.4% (Riemer et al. 2001). In the Rogue River, the occurrence of salmonids ranged from 10.3–14.8%. The number of salmonids taken by pinnipeds ranged from four to 177 in the Alsea River and 218 to 249 in the Rogue River. The estimates likely represent lower bounds on total predation during the course of the study (Riemer et al. 2001).

Wright et al. (2007) assessed harbor seal predation on adult salmonids in the Alsea River estuary during the fall of 2002. Through diurnal observations of harbor seal foraging behavior, Wright et al. (2007) determined that seals consumed at least 500–1,800 adult salmonids in the Alsea River estuary during fall 2002. However, adult salmonid remains were only found in 9.4% of scat samples containing remains, providing evidence that salmonids were a relatively small part of the harbor seals' diet during the study. Wright et al. (2007) further concluded that management actions to reduce predation pressure by seals are unwarranted at this time, and that factors other than predation are primarily influencing coho salmon population dynamics in the basin.

Harbor seals are also common in the estuary of the Umpqua River, where they were suspected of having an impact on recovery of sea-run cutthroat trout (Orr et al. 2004). Harbor seals in the lower Umpqua River consumed prey from over 35 taxa, and salmonid remains were found in only 6% of harbor seal scats collected during the study.

Diet studies provide information about the prey of pinnipeds, but estimates of consumption should be regarded as a lower bound or minimum impact, for several reasons. First, seals do not capture all of the prey they pursue. Some fish prey may escape unharmed or with varying degrees of injuries. Second, seals may only consume the soft tissue of the fish they capture (especially of larger prey), which would not leave identifiable evidence in scats (Orr et al. 2004). Lastly, "because skeletal remains from different prey species pass through the alimentary canal and erode at different rates, they may not reflect the true number or proportions of prey consumed" (Orr et al. 2004, p. 114). Regardless, studies indicate that pinnipeds prey on a wide variety of fish species. Salmonids appear to be a minor part of their diet, but total consumption could be substantial in some cases.

Killer whales are classified as top predators in the food chain and are the world's most widely distributed marine mammal. Fish-eating killer whales in the northeastern Pacific consume at least 22 species of fish and at least one species of squid (Ford et al. 1998, 2000, Ford and Ellis 2006, Ford et al. 2016, Hanson et al. 2021), but salmon are their primary prey. Four populations of Resident killer whales occur in the Pacific Northwest: Southern Residents; Northern Residents; Southern Alaska Residents; and Western Alaska North Pacific Residents. The far-north migrating OC Chinook salmon may therefore be prey to multiple geographically distant killer whale populations.

The diet of killer whales is the subject of ongoing research, including direct observation of feeding, scale and tissue sampling of prey remains, and fecal sampling. The diet data suggest that they are consuming mostly larger (i.e., generally age-3 and up) Chinook salmon (Ford and Ellis 2006). Scale and tissue sampling from May to September in inland waters of Washington and British Columbia, Canada, indicate that their diet consists of a high percentage of Chinook salmon (monthly proportions as high as >90%; Hanson et al. 2010, Ford et al. 2016). Ford et al. (2016) confirmed the importance of Chinook salmon to Resident killer whales in the summer months using DNA sequencing from whale feces. Salmon and steelhead made up to 98% of the inferred diet, of which almost 80% were Chinook salmon. Coho salmon and steelhead are also found in the diet in inland waters in spring and fall months when Chinook salmon are less abundant (Ford et al. 2016, Hanson et al. 2021).

Chasco et al. (2017) estimated that, while production of wild and hatchery Chinook salmon increased between 1975 and 2015 and harvest levels decreased, the increased consumption by sea lions, harbor seals, and killer whales more than offset the first two. Based on the model results, for stocks that have a longer migration route, such as those from the Oregon coast, predation impacts have increased strongly over time, exceeding harvest in recent years. The longer migration routes expose these stocks to more predation by marine mammals. Killer whales account for two-thirds of the total biomass of Chinook salmon consumed by these predators, with the largest increase in consumption being from Northern Resident killer whales along the coasts of British Columbia.

Other marine predators

A variety of piscivorous marine predators have been identified, including sculpins, cod, dogfish, Pacific hake (whiting), mackerel, and lamprey. Beamish et al. (1992) documented predation of hatchery-reared Chinook and coho salmon by spiny dogfish (*Squalus suckleyi*). Beamish and Neville (1995) estimated that lamprey kill millions of juvenile Chinook salmon in the Fraser River plume annually. Seitz et al. (2019) noted that salmon shark predation may be a substantial source of oceanic mortality of immature and maturing Chinook salmon in the Gulf of Alaska. They also speculated that protections afforded by the Magnuson–Stevens Act (MSA; starting in 1976) have likely contributed to increases in abundance of salmon sharks in the northern Pacific Ocean. Based on the results of their study, Seitz et al. (2019) speculated that Pacific halibut or sleeper shark may also be predators of Chinook salmon.

Freshwater predation

OC Chinook salmon ESU

Smallmouth bass is a non-native freshwater fish species found in Pacific coastal lakes and streams, introduced widely for sport fish purposes. Smallmouth bass are predators with a varied diet and are known to prey on young salmonids, especially Chinook salmon, in circumstances where they co-occur (Fritts and Pearsons 2004, Carey et al. 2011). Smallmouth bass may also behaviorally harass or otherwise stress small Chinook salmon (Kuehne et al. 2012), and potentially exclude young-of-year salmonids from prime foraging locations in river littoral habitat, pools, and glides in streams, especially where bass are brooding and rearing young.

ODFW's coastal multispecies plan (ODFW 2014) notes avian, marine mammal, and non-native fishes as having the potential to negatively affect the abundance of both adult and juvenile salmonids. Kostow (1995) and ODFW (2014) noted that a substantial smallmouth bass population in the lower mainstem Umpqua River is of particular concern, as they have been shown to prey extensively on juvenile Chinook salmon in rivers and reservoirs.

Smallmouth bass were illegally introduced into the Coquille River sometime prior to 2011, when a reproducing population was confirmed. Since then, the population has grown and expanded their range up to the Forest Service boundary above Powers in the South Fork, up to Laverne Park in the North Fork, and up to Sandy Creek in the Middle Fork (ODFW 2022). "Although wild fall Chinook in the Coquille suffered from poor ocean conditions, predation by smallmouth bass is the primary reason these fish have not rebounded to the same extent as in other coastal rivers" (ODFW 2022). ODFW is actively trying to remove smallmouth bass from the Coquille River to reduce predation on juvenile wild fall Chinook salmon.

SONCC Chinook salmon ESU

Umpqua pikeminnow were illegally introduced into the Rogue River in the 1970s. Pikeminnow consume juvenile Chinook salmon and steelhead, and compete with native fishes for food and space. The Rogue Spring Chinook Salmon Conservation Plan includes a management action to encourage fishing-related mortality of non-native pikeminnow (ODFW 2007b).

In addition, hatchery-produced coho salmon and steelhead consume the fry of naturally produced spring Chinook salmon. Surveys from 1979–81 estimate that the total annual number of spring Chinook salmon fry consumed by hatchery coho salmon and steelhead was between 163,000 and 275,000, representing 3–7% of Rogue River spring Chinook salmon fry production during those years (ODFW 2007b).

The effect of predation on Chinook salmon in the Klamath River basin is not well understood. Pinniped predation on adult salmon can significantly affect escapement numbers within the Klamath River Basin. Hillemeier (1999) assessed pinniped predation rates within the Klamath River estuary during August, September, and October 1997, and estimated that a total of 8,809 adult fall Chinook salmon (8.8% of the estimated fall Chinook salmon run) were consumed by seals and sea lions during the study perioD.California sea lions were the primary pinniped predator, accounting for 87% of the impacts on salmonids. While the extent of predation is not well understood, some level of predation is known to be occurring, and the associated mortality and lost production is likely having some adverse effect on Chinook salmon in the Klamath River basin.

Risk Factor 4: Inadequacy of Existing Regulatory Mechanisms to Address Identified Threats

A variety of federal, state, tribal, and local laws, regulations, treaties, and measures affect the abundance and survival of U.S. West Coast Chinook salmon and the quality of their habitat. NMFS (1998) found that the serious depletion of Chinook salmon and other anadromous salmonids, coupled with the poor health and low abundance of many distinct populations of Chinook salmon, was an indication that existing regulatory mechanisms had largely failed to prevent the depletion. Since then, the various agencies have worked on addressing this issue. Below, we summarize the current management plans/strategies for federal and state agencies.

Federal land and water management

U.S. Forest Service

The OC and SONCC Chinook salmon ESUs overlap several national forests in Oregon and California. The Siuslaw National Forest operates under a 1990 Forest Plan and a programmatic consultation with NMFS. On 3 September 2020, NMFS issued Biological Opinion and Magnuson–Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Siuslaw National Forest Vegetation and Aquatic Restoration Program. In the biological opinion, NMFS determined that the proposed action was not likely to jeopardize the continued existence of OC coho salmon or Upper Willamette River steelhead, or destroy or adversely modify their designated critical habitat. We think it is reasonable to believe that these measures will also be protective of Chinook salmon. The incidental take statement describes reasonable and prudent measures NMFS considers necessary or appropriate to minimize the impact of incidental take associated with the program. The incidental take statement also sets forth nondiscretionary terms and conditions, including reporting requirements, that the federal action agency must comply with to carry out the reasonable and prudent measures. The MSA consultation concluded that the action would adversely affect the essential fish habitat of Pacific coast salmon. Therefore, NMFS included conservation recommendations to avoid, minimize, or otherwise offset potential adverse effects on essential fish habitat. These measures were for coho salmon and steelhead, but are also likely to be protective of Chinook salmon.

The Umpqua and Rogue River–Siskiyou National Forests follow the Northwest Forest Plan. The Northwest Forest Plan is a federal management policy with important benefits for Chinook salmon. While the Northwest Forest Plan covers a very large area, its overall effectiveness in conserving Chinook salmon is limited by the extent of federal lands and the fact that federal land ownership is not uniformly distributed in watersheds within the affected ESUs. The extent and distribution of federal lands limits the Northwest Forest Plan's ability to achieve its aquatic habitat restoration objectives at watershed and river-basin scales, and highlights the importance of complementary salmon habitat conservation measures on nonfederal lands within the subject ESUs.

The Six Rivers National Forest (SRNF) follows the Northwest Forest Plan, and also has two landscape-level programs designed to improve habitat for species, including NMFS-listed species. The first is the SRNF Watershed and Fisheries Restoration Program, a 15-year program designed to restore watershed processes and enhance instream habitat throughout the SRNF (NMFS 2015). The second is the Thinning and Fuels Reduction Program, which includes, among other goals, wildlife habitat improvement and maintenance by improving ecological conditions (NMFS 2019b). These two programs do encourage standards and measures to address threats, and encourage recovery actions by streamlining consultation and permitting, above the Northwest Forest Plan.

The Smith River National Recreation Area is part of the SRNF and is not a wilderness, but a public recreation management area with some added conservation over standard National Forest lands. This area, like all of the SRNF, is managed under the Northwest Forest Plan, in addition to the two landscape-level programmatic components mentioned above.

Bureau of Land Management

The Bureau of Land Management (BLM) administers 2.5 million acres of land in western Oregon. In 2016, BLM revised the resource management plans (RMPs) for the Coos Bay, Eugene, Medford, Roseburg, and Salem Districts, and for the Klamath Falls Field Office of the Lakeview District. The RMPs define the management direction for specified areas of BLM-administered lands (typically, for individual BLM districts or BLM resource areas). Resource management plans are formally evaluated periodically to determine whether there is a significant cause for amending or revising them.

BLM requested consultation for the RMPs, and NMFS issued a Biological Opinion and Magnuson–Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation on 15 July 2016 (NMFS 2016c). NMFS's biological opinion concluded that the proposed action is not likely to jeopardize the continued existence of OC coho salmon, SONCC coho salmon, Lower Columbia River (LCR) Chinook salmon, LCR steelhead (*O. mykiss*), LCR coho salmon, Columbia River chum salmon (*O. keta*), Upper Willamette River (UWR) Chinook salmon, UWR steelhead, Snake River (SR) spring/summer-run Chinook salmon, SR fall-run Chinook salmon, Upper Columbia River (UCR) spring-run Chinook salmon, Snake River (SR) sockeye salmon (*O. nerka*), Middle Columbia River steelhead, UCR steelhead, Snake River basin steelhead, southern DPS of eulachon (*Thaleichthys pacificus*), and southern DPS of green sturgeon (*Acipenser medirostris*), or result in the destruction or adverse modification of their designated critical habitats. The same is likely to be true for OC and SONCC Chinook salmon.

NMFS's document also included the results of an analysis of the action's likely effects on essential fish habitat (EFH) pursuant to Section 305(b) of the MSA, and includes two conservation recommendations to avoid, minimize, or otherwise offset potential adverse effects on EFH. The action area for BLM's RMP includes EFH for OC and SONCC Chinook salmon. Elements of the biological opinion and EFH consultation were included in the final RMPs' two records of decisions.

Following BLM's issuance of records of decision for the two RMPs, BLM and NMFS engaged in discussions to identify opportunities to improve ESA and MSA consultation efficiencies for implementing actions tiered to the new RMPs. The records of decision and RMPs provide overall direction for management of all resources on BLM-administered lands. The decisions in the RMPs guide future land management actions and subsequent site-specific implementation decisions. When BLM proposed the RMPs, it was not proposing to authorize many of the site-specific projects that would occur under the plans (including forest management projects); rather, BLM anticipated granting those authorizations and undertaking associated ESA consultations in the future. NMFS subsequently issued a Biological Opinion and Magnuson–Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for a suite of individual actions—known as BLM's Forest Management Program—implemented over a 20-year period.

Redwood National and State Parks

The Redwood National and State Parks have been proactive about conservation and restoration on their lands, including partnering with the Save the Redwoods League and Redwoods Rising to implement ecosystem recovery programs in Prairie Creek and Mill Creek, two salmon strongholds.

State land management

The Oregon Forest Practices Act (OFPA) stream rules were amended in 2017 for southwestern Oregon to increase buffer widths by 10 feet and retain more trees on private forestlands (Oregon Administrative Rule 629-645-0000). These rules became effective 1 July 2017 and might improve water quality by increasing shade and reducing sedimentation. Some of the highest-quality salmon and steelhead rearing habitat is on private forestlands, making these rule changes particularly important for the conservation of salmon and steelhead. However, we remain concerned that rules regarding road maintenance and density on private forest lands are still not adequate to address these activities' ongoing impacts on water quality. While buffer widths were recently increased, it is not yet known whether they are now sufficient to adequately protect water quality for OC and SONCC Chinook salmon.

Approximately 567,000 acres (2,295 km^2) of forest land within the range of OC coho salmon are managed by the Oregon Department of Forestry (ODF 2005). The majority of these lands are managed under the Northwest Oregon Forest Management Plan and the Elliott Forest Management Plan. NMFS is collaborating with ODF to develop a habitat conservation plan (HCP) for state forest lands (722,676 acres/2,925 km^2) within western Oregon. In 2021, NMFS issued a notice of intent to prepare an environmental impact statement on the Western Oregon State Forests Habitat Conservation Plan (USOFR 2021a). The Western Oregon State Forests HCP is in the early National Environmental Policy Act (NEPA) process and, if approved, is expected to be finalized in 2023. Additionally, NMFS is collaborating with the Oregon Department of State Lands (DSL) on an HCP on the Elliott State Lands.

The California Department of Forestry and Fire Protection enforces the State of California's forest practice rules, which are promulgated through the Board of Forestry. NMFS (1998) found California's State Forest Practice Rules provided inadequate protection for salmon and steelhead habitat. Many of the identified inadequacies have been ameliorated through regulation changes by the State Board of Forestry. The most notable rule changes with input from NMFS, CDFW, and other state agencies are the 2010 Anadromous Salmonid Protection Rules and the 2012 Road Rules. These rules have resulted in expanded stream-buffer widths, less-damaging road and harvest techniques, and limits on riparian harvesting that will collectively improve instream and riparian habitat and function over the long term. Additionally, some private timber companies are actively restoring damaged aquatic and upslope habitat by increasing instream large woody debris volume or abating upslope erosion sources. The State Forest Practice Rules have also made additional changes to the cumulative watershed effects analysis of proposed timber harvest practices. Although the California Forest Practice Rules expressly do not allow take of federally listed species such as threatened or endangered salmonids, application of the current California Forest Practice Rules likely results in take in some instances at some locations. However, much of the timber harvest activity that occurs in the range of the ESU occurs on either tribal or private land, and is managed by either a Tribal Forest Management Plan (Yurok Tribe 2012) or an HCP (GDRC 2006).

Private timber land management

In 2019, Oregon Governor Kate Brown announced that representatives of the timber industry and conservation groups had agreed to jointly pursue new forestry reforms (called the Private Forest Accords) in Oregon. On 30 October 2021, timber and conservation groups reached an unprecedented conservation agreement on the Private Forest Accords. The agreement represents changes to the OFPA to better protect salmon and steelhead habitat on more than 10 million acres of private forestlands. These changes would dramatically improve Oregon's forestry rules, including improving water quality, large wood retention, increased riparian no-cut buffers, and commitments to upgrade culverts with new standards for fish passage. Agreement parties expect an HCP based on enacted legislation will be developed under the ESA for consideration by NOAA Fisheries and the U.S. Fish and Wildlife Service (USFWS).

In California, new rules for managing timber harvest on certain private lands were adopted in 2012. These rules have resulted in expanded stream-buffer widths, less-damaging road and harvesting techniques, and limits on riparian harvesting that will collectively improve instream and riparian habitat and function over the long term.

Habitat conservation plans

In 2007, NMFS and USFWS approved Green Diamond's Aquatic Habitat Conservation Plan and Candidate Conservation Agreement with Assurances (AHCP) for implementation on over 400,000 acres of timberland in northern California. The SONCC Chinook salmon ESU is a covered species addressed by the conservation measures in the AHCP. The AHCP was approved after several years of technical review by both NMFS and USFWS, and after extensive public review and comment. The approval of the AHCP is based on a substantial administrative record including detailed decision documents such as a final environmental impact statement, record of decision, ESA Section 10 findings, and a biological opinion prepared by NMFS. The record reflects years of effort by NMFS and USFWS personnel and it substantiates NMFS's conclusion that Green Diamond's forest management activities under the AHCP will contribute to the conservation of salmonid species including SONCC Chinook salmon.

Tribal lands in California

There is significant tribal land in the SONCC Chinook salmon range in California. The Tolowa Dee-ni' Nation on the Smith River does not have an HCP, but does operate a small hatchery on Rowdy Creek, a tributary to the Smith River, that includes the Hatchery and Genetic Management Plan (Tolowa Dee-ni' Nation 2018) for their Chinook salmon program. NMFS completed a biological opinion for the hatchery operations in 2019. The Yurok Tribe are actively involved in much of the salmon recovery work in their ancestral lands, including on Redwood/Prairie Creek watershed and on the Lower Klamath River. The Yurok Tribe developed the Tribal Forest Management Plan (Yurok Tribe 2012), the Tribal Fisheries Research and Monitoring Plan (Yurok Tribe 2018) that is consistent with the ESA Section 4(d) limit for tribal plans (NMFS 2019a), and annual harvest management plans.

Oregon's cooperative management agreements with tribes

In June 2022, the Oregon Fish and Wildlife Commission and the Coquille Indian Tribe adopted a memorandum of agreement to establish a voluntary, cooperative partnership to collaborate, share resources, and work as partners to develop and implement plans to protect, restore, and enhance fish and wildlife populations and their habitat within a specific geography of Oregon. The agreement to establish this partnership also set up a framework under which Coquille tribal members will participate in subsistence and ceremonial harvest of fish and wildlife resources that is licensed and managed by the tribal government in partnership with ODFW and the Oregon State Police.

The geographic scope of the memorandum of agreement is all of Coos, Curry, Douglas, Lane, and Jackson Counties, including the associated nearshore marine areas. Within these counties, enrolled members of the Coquille Indian Tribe will be able to participate in hunting, fishing, and trapping licensed by the tribe. ODFW and the tribe will also coordinate on proactive fish, wildlife, and habitat conservation activities in this five-county area.

The memorandum of agreement includes a framework for Coquille tribal members to participate in subsistence and ceremonial harvest of fish and wildlife resources within the defined geography. Harvest of fish and wildlife by tribal members would be regulated, licensed and enforced by the tribal government in partnership with ODFW and the Oregon State Police. Annual harvest limits and areas will be set by mutual consent between the Tribe and ODFW.

The memorandum of agreement is limited to subsistence and ceremonial harvest. The Coquille Indian Tribe will not be implementing any commercial harvest opportunities. "Subsistence harvest" is harvest consistent with tribal cultural practices for acquiring traditional foods and other resources for personal, familial, or community sharing. Subsistence harvest is likely to occur during generally similar times and in similar locations to the state's usual harvest opportunities, but some differences should be anticipated. "Ceremonial harvest" provides traditional foods for tribe- or community-wide events that acknowledge and perpetuate religious, cultural, and other traditions (First Salmon celebration, Winter Solstice). It may also include other traditional family group ceremonies (funerals, births, name-givings). Ceremonial harvest may occur throughout the year.

In December 2022, the Oregon Fish and Wildlife Commission and the Cow Creek Band of Umpqua Indians adopted a memorandum of agreement that advances the government-to-government relationship between the state and the tribe, enhances tribal sovereignty, enhances the tribe's ability to contribute to positive outcomes for fish and wildlife, and will increase opportunities for tribal members to harvest fish and wildlife resources consistent with tribal values. The memorandum of agreement between Oregon and the tribe will strengthen the ability of the tribe to engage in this important fish and wildlife conservation work that will benefit all Oregonians.

The geographic scope of the memorandum of agreement is all of Douglas, Lane, Jackson, Josephine, and Coos Counties, including the associated nearshore marine areas. This is a portion of the tribe's federal service area which both the state and federal governments recognize as the area in which the tribe administers certain federal programs under tribal self-determination. Within this geography, enrolled members of the Cow Creek Tribe would be able to participate in hunting, fishing, trapping, and gathering licensed by the tribe. ODFW and the tribe will also coordinate on proactive fish, wildlife, and habitat conservation activities in this area.

The Oregon Fish and Wildlife Commission and the Confederated Tribes of Siletz Indians are working on a similar agreement.

Oregon's road maintenance program

Since 9 June 1999, the Oregon Department of Transportation (ODOT) has implemented the Routine Road Maintenance Program (Program). The Program includes measures carried out during road maintenance to protect threatened salmon, steelhead, and their habitat. The Program is depicted in the ODOT Routine Road Maintenance Water Quality and Habitat Guide Best Management Practices (Blue Book). ODOT reviews the Blue Book every five years to determine if the best management practices (BMPs) continue to be effective. The last five-year review occurred in 2019 and into 2020. In June 2020, ODOT submitted its updated Blue Book to NMFS. In the latest version of the Blue Book, ODOT modified BMPs around beaver dam removal to ensure steps are taken to reduce the likelihood that listed fish would get stranded. The BMP changes were in response to concerns raised by both NMFS and ODFW. ODOT made additional revisions regarding water quality protection:

- Updated erosion and sediment control references to the 2016 Erosion and Sediment Control Guide for Road Maintenance.
- Added BMPs to the beaver dam removal activity to reduce the risk of stranding listed fish.
- Added a description of beaver dam alteration activities to the annual reporting commitment.

California's road maintenance program

The effects of routine road maintenance in California to NMFS listed species are generally consulted on using a 2013 programmatic biological opinion (PBO; NMFS 2013). Projects that do not qualify for inclusion under the PBO, usually because the PBO does not include pile driving, are guided toward similarly protective BMPs during technical assistance. Projects that include pile driving follow predicted injury thresholds from hydroacoustic impacts and methods to minimize/avoid injury, as described in CalTrans (2020), Technical Guidance for the Assessment of Hydroacoustic Effects of Pile Driving on Fish.

Federal Clean Water Act

The federal Clean Water Act (CWA) of 1972 addresses the development and implementation of water-quality standards, the development of Total Maximum Daily Loads (TMDLs),[9] filling of wetlands, point-source permitting, the regulation of stormwater, and other provisions related to protection of United States waters. Some authority for clean water regulation is retained by the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (USACE), and some authority is delegated to the states of Oregon and California.

Under Section 303(d) of the CWA, states, territories, and authorized tribes are required to develop lists of impaired waters that do not meet the water-quality standards set by states. The law requires that states establish priority rankings for waters on the lists and develop TMDLs for these waters. A TMDL includes a calculation of the maximum amount of a pollutant that can be present in a waterbody and still meet water-quality standards. However, TMDLs do not always include implementation policies and action plans that describe the specific actions needed to improve impaired watersheds.

A significant number of stream reaches in the range of the OC and SONCC Chinook salmon ESUs do not currently meet water-quality standards. The Oregon Department of Environmental Quality (ODEQ) published the 2018/2020 Integrated Report, which was approved by EPA in November 2020. The most common impairment is that of the fish and aquatic life use. This is largely driven by nonattainment of the temperature criteria, suggesting that the TMDLs are currently not sufficient to restore water quality in impaired waters.

USACE regulates the discharge of dredged and fill material into waters of the United States (WOTUS), including wetlands, through permitting under the CWA Section 404 Program. The CWA 404 standard is that permitted activities should not "cause or contribute to significant degradation" of the WOTUS (40 CFR 230.10(c)). Activities that are regulated under this program include fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and mining projects. Section 404 requires a permit before dredged or fill material may be discharged into

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[9] A TMDL is a pollution budget that includes a calculation of the maximum amount of a pollutant that can occur in a waterbody and allocates the necessary reductions to one or more pollutant sources. A TMDL serves as a planning tool and potential starting point for restoration or protection activities, with the ultimate goal of attaining or maintaining water-quality standards.

WOTUS, unless the activity is exempt from Section 404 regulation (e.g., certain farming and forestry activities). CWA 404 permit exemptions, particularly those affecting agricultural and transportation activities, therefore fail to prevent the degradation of tributary and mainstem habitat conditions resulting from these activities.

USACE guidelines do not specify a methodology for assessing cumulative impacts or how much weight to assign them in decision-making. USACE continues to lack a comprehensive and consistent process to address the cumulative effects of the continued development of waterfront, riverine, coastal, and wetland properties.

USACE authorizes certain floodplain fill and removal activities with nationwide permits (NWPs). In 2021, USACE finalized the reissuance of existing nationwide permits with modifications (USOFR 2021c,d). The modifications are likely to increase the amount of fill and destruction of floodplain habitat allowed for nationwide permits. The NWP authorizations will disconnect off-channel stream and floodplain areas and result in simplification of stream habitats.

On 25 May 2023, the Supreme Court, ruling in Sackett v. Environmental Protection Agency, 598 U.S. 651 (2023), redefined the Clean Water Act's coverage of WOTUS. In its opinion, the Supreme Court ruled that the CWA extends protection only to those waters that are described "in ordinary parlance" as "streams, oceans, rivers, and lakes," and to wetlands only if those wetlands have a "continuous surface connection" to such waters "making it difficult to determine where the water ends and the wetland begins." One potential outcome would be a decline in water quality resulting from changes in regulation of activities in seasonally flooded floodplain wetlands and other areas outside of typical anadromous habitats. The extent to which this affects OC and SONCC Chinook salmon habitat will depend in large part on how EPA and USACE choose to implement the Supreme Court's ruling.

Agricultural regulatory mechanisms

On the coast of Oregon, federal, state, and private landownership is generally characterized by forest, agricultural, and municipal land-use activities. Riparian management policies are fragmented and not well integrated. State and federal agencies' rules for riparian land management involve separate rules based on jurisdiction, resulting in a range of standards for managing riparian conditions. These varied policies create diverse protection mechanisms, which influence varying ecological outcomes.

ODEQ is the primary state agency responsible for implementing the CWA and general state water-quality laws. ODEQ establishes water-quality standards to protect designated and existing beneficial uses, developing TDMLs under the CWA. Water-quality standards are adopted as rules and approved by the EPA.

Oregon's Agriculture Water Quality Management Act authorizes the Oregon Department of Agriculture to develop agricultural water-quality management area plans and rules throughout the state; these are intended to be the implementation measures to prevent and control nonpoint-source pollution from agricultural lands. More specifically, Oregon's

Agriculture Water Quality Management Act authorizes the Oregon Department of Agriculture to develop and implement any program or rules that directly regulate farming practices to protect water quality. The Oregon Department of Agriculture area rules serve as a regulatory backstop to the voluntary efforts described in the area plans.

Area plans identify strategies to prevent and control water pollution from agricultural lands through a combination of outreach programs, suggested land treatments, management activities, compliance, and monitoring. The area plan is neither regulatory nor enforceable, and the provisions of the area plan do not establish legal requirements or prohibitions. Each area plan is accompanied by area rules that describe local agricultural water-quality regulatory requirements. Oregon's Agriculture Water Quality Management Act area plans and rules are intended to be the implementing measures of the water-quality standards adopted by ODEQ.

While area plans are intended to prevent and control water pollution from agricultural activities and to achieve water-quality standards, the state's management is a voluntary, "outcome-based" approach to protecting water quality from agricultural lands. Oregon's Agriculture Water Quality Management Act area plans and rules do not require a vegetated riparian buffer on stream-adjacent land for any stream type to protect water quality from agricultural land uses, although some area-specific plans voluntarily require establishment of riparian vegetation to moderate water temperatures and for bank stability to prevent erosion. Compared to a "prescriptive" approach that includes land-management regulatory measures designed to reduce impacts from land uses (e.g., forestry's protective riparian buffers), only after repeated violations of water-quality standards are agricultural land activities in Oregon subject to regulatory enforcement. Thus, the policies respond to, rather than prevent, pollution from agricultural lands.

Many of the wide, low-gradient valley bottoms in coastal Oregon watersheds have been historically converted for agricultural production. Across the coast, the percentage of agricultural lands that make up streamside lands, and thus the percent of lands subject to voluntary, outcome-based standards (nonprescriptive riparian standards) to protect water quality, varies greatly by watershed. Where agricultural lands occur, adjacent aquatic ecosystems and processes rely on voluntary efforts of landowners to manage for ecological goals, including the management of riparian vegetation. Nevertheless, there are many examples of agricultural landowners supporting habitat restoration projects on and adjacent to their lands. Watershed groups regularly work closely with land owners to incentivize and promote the co-benefits of habitat restoration on agricultural lands.

In some watersheds along the coast of Oregon, summer instream flows are very low during certain water year types. Under Oregon law, all water users, including agriculture, must obtain a permit or license from the Water Resources Department (OWRD) to use water from any source, whether it is underground, or from lakes or streams. Applying for and obtaining a water use permit is the first step in securing a water right. Oregon law requires that all water that is diverted by water right holders be used beneficially and without waste. OWRD recognizes that water resource needs in Oregon are many, while water resources are finite, so it encourages the efficient use of water and practices that conserve water resources. OWRD has several programs and efforts to assist with water conservation. These include planning tools and resources, modifications to water rights, and information about watershed restoration and instream activities.

Much of the Klamath River basin is currently listed as water-quality impaired under Section 303(d) of the CWA. Water temperatures within both mainstem and tributary reaches are often stressful to juvenile and adult coho salmon (and presumably Chinook salmon) during late spring, summer, and early fall months. The Klamath River from the Trinity River confluence to the mouth is listed as impaired for water temperature, sedimentation, organic enrichment/low dissolved oxygen, and nutrients (FERC 2021).

The Smith River basin is relatively high-gradient, except for in areas close to the estuary. Therefore, large-scale agriculture in the Smith River basin—predominantly lily bulb cultivation—only occurs in the lower basin and estuary. Some negative impacts to water quality in the Smith River basin as a result of lily bulb cultivation have been reported, but the North Coast Regional Water Quality Control Board developed a water-quality management plan in 2021 to meet water-quality standards through the control of waste discharges associated with lily bulb operations in the Smith River plain.

Fisheries regulations

The regulation of most ocean fisheries that impact OC Chinook salmon takes place under the PST or PFMC. Stock-specific abundance forecasts generate indices for abundance and inform annual catch limits for three major mixed-stock Chinook salmon fisheries, one in Alaska and two in British Columbia (known as Aggregate Abundance-Based Management [AABM] fisheries). Other fisheries in British Columbia, Washington, and Oregon are determined with the aim of meeting management objectives for individual component stocks (known as Individual Stock-Based Management [ISBM]). Both AABM and ISBM fisheries capture OC Chinook salmon. Fisheries off Washington and Oregon are determined by a separate process involving NOAA, PFMC, the states of Washington and Oregon, tribal nations, and other stakeholders. Ocean fisheries must be in accordance with legal obligations under the PST, treaties, court decisions between Native American tribes and the United States, and conservation constraints of the Endangered Species Act.

Within the OC Chinook salmon ESU, for the North Oregon aggregate, hatchery releases from the Salmon River serve as the exploitation indicator and the Nehalem, Siletz, and Siuslaw Rivers are the escapement indicator stocks. For the Mid-Oregon aggregate, hatchery releases from the Elk River are the exploitation indicator and the South Umpqua and Coquille River stocks are the escapement indicators. Note that spring-run Chinook salmon from the OC ESU (most notably the Umpqua River) are not included in the CTC model and therefore do not have estimated exploitation rates.

For the SONCC Chinook salmon ESU, the vast majority of ocean fishery impacts take place within areas managed by PFMC. PFMC considers Klamath River fall Chinook (KRFC) an “indicator stock” for the SONCC stock complex that consists of the stocks constituting the SONCC Chinook salmon ESU as well as the Upper Klamath/Trinity ESU (PFMC 2022, pp. 21–22). Due to broadly similar ocean spatial distributions, age-specific ocean harvest rates are likely broadly similar among the stocks in the stock complex, but could vary based on return timing and effects of ocean fisheries near river mouths of the respective source populations. In addition, the cumulative impacts of ocean fisheries will differ depending on maturation schedules, i.e., greater cumulative impacts of ocean fisheries on stocks maturing at later ages. Fall- versus spring-run stocks may be most vulnerable to fisheries at different times of year. Assuming similar maturation schedules, spring-run stocks may be less exposed to ocean fisheries due to their earlier run timing that avoids summer ocean fisheries in the year of return.

KRFC is the only stock in the stock complex for which ocean harvest rates are actively managed. Thus, there is no means for adjustment of SONCC Chinook salmon ocean harvest rates in response to information on SONCC Chinook salmon abundance.

Entering the preseason process, allowable planned ocean impact rates for KRFC reflect three primary constraints:

1. A control rule (PFMC 2022, pp. 32–33) limits the maximum allowable planned exploitation rate as a function of forecasted KRFC abundance. At the highest forecasted abundances, planned total exploitation rates must be no greater than the acceptable biological catch, F_{ABC}, of 0.68. The F_{ABC} reflects application of a 5% uncertainty buffer to the maximum sustainable yield, F_{MSY}, value of 0.71 estimated from a spawner–recruit relationship fit to data for KRFC (STT 2005; see also PFMC's salmon fishery management plan[10] for additional details about fishing mortality rates).
2. When forecasted abundances are high enough that an escapement of 40,700 natural adults (representing S_{MSY}, the spawning escapement estimated to produce maximum sustainable yield) can be achieved in expectation with exploitation rates of at least 25%, the maximum allowable planned exploitation rate is set equal to the rate that produces 40,700 natural adult spawners in expectation (subject to the constraint that the planned exploitation rate cannot exceed F_{ABC}). For lower forecasts, "de minimis" exploitation rates ≤ 25% are allowed with tiered reductions as forecasted abundances decrease. A decision by the Solicitor of the Department of the Interior in 1993 (USDOI 1993) codified a right of Klamath River basin tribes to 50% of the harvestable surplus of KRFC. Because the tribal fisheries are all in-river, this limits the allowable ocean exploitation rate to no more than half of the allowable total exploitation rate (and in practice, there are usually further allocations to in-river recreational fisheries as well).
3. Since 2000, the ESA consultation standard for California Coastal Chinook salmon has limited the planned age-4 ocean harvest rate for KRFC to no more than 17% (NMFS 2000), subsequently revised to 16% due to modifications to the KOHM (Klamath River Technical Advisory Team 2002). However, postseason estimates of the age-4 KRFC ocean harvest rate have substantially exceeded 16% due to model errors in recent years (NMFS 2022b).

In addition to these primary constraints, planned ocean impacts on KRFC may be limited by mixed-stock fishery constraints due to low abundance forecasts for co-occurring stocks, restrictions to protect listed SONCC coho salmon, or by supplemental guidance from NMFS and/or PFMC to take a more precautionary approach than the maximum fishing intensity allowed by all the relevant control rules and consultation standards. For example, in 2008–09, ocean fisheries off California and most of Oregon were closed due to low abundance forecasts for Sacramento River fall Chinook salmon and the control rule in effect for that stock at that time (Carlson and Satterthwaite 2011). In 2022, NMFS issued

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[10] https://www.pcouncil.org/fishery-management-plan-and-amendments-3/

guidance to target a lower KRFC age-4 ocean harvest rate than the 16% allowed under the California Coastal Chinook salmon consultation standard due to pre-season planning models consistently underpredicting the harvest rates estimated to have actually occurred (NMFS 2022). In 2023, directed Chinook salmon ocean fisheries off California and much of Oregon were closed due to low abundance forecasts for both major California fall-run Chinook stocks and poor recent performance of management models, even though the relevant control rules and consultation standards as well as supplemental NMFS guidance would still allow for some fishing (PFMC 2023).

It is difficult to predict which of these factors will be most limiting to fishery impacts on KRFC in any given year, but PFMC (2019) offers a retrospective analysis of the factors inferred to have been most limiting for 2004–18.

Smith River Chinook salmon (spring and fall runs combined) are a named stock in PFMC's Salmon Fishery Management Plan (SFMP; PFMC 2022, p. 21), but they do not have a conservation objective nor do they have S_{MSY} or M_{SST} (minimum stock size threshold) reference points established. The default Chinook salmon proxy F_{MSY} of 0.78 (derived as the average of estimates for other stocks with estimated spawner–recruit relationships) is assumed to apply, but no exploitation rates are calculated for comparison with this value.

For Southern Oregon Chinook salmon, the SFMP established a conservation objective of an escapement of 41,000 at Huntley Park on the Rogue River (PFMC 2022, p. 22) along with an S_{MSY} of 34,992 and an M_{SST} of 20,500. Pre-season forecasts of Rogue River fall Chinook salmon abundance are made, but performance of this predictor is not evaluated (PFMC 2023, p. 18) and there is no model for planning total exploitation rates on Rogue River Chinook. Age-specific ocean harvest rates are assumed equal to those estimated for KRFC (PFMC 2023, their Table II-7), but river harvest rates and thus total exploitation rates are not tracked by PFMC. The same analysis that provided the basis for the S_{MSY} of 34,992 also indicated an F_{MSY} of 0.54 (ODFW 2014b), and PFMC's Salmon Technical Team and Scientific and Statistical Committee both recommended adoption of this value, but it was not adopted by PFMC. Instead, PFMC still uses the proxy F_{MSY} of 0.78 for Southern Oregon Chinook salmon.

The choice of F_{MSY} for Southern Oregon Chinook salmon may be of limited practical importance because no post-season estimate of the exploitation rate is made to compare with the F_{MSY} reference point. However, in years with high ocean harvest rates as estimated for KRFC, it would not take very high river harvest rates to bring total exploitation rates above the lower value recommended for F_{MSY} by PFMC's scientific advisors.

National Flood Insurance Program

The National Flood Insurance Program (NFIP) is a federal benefit program that extends access to federal monies or other benefits, such as flood disaster funds and subsidized flood insurance, in exchange for communities adopting local land-use and development criteria consistent with federally established minimum standards. Under this program, development within floodplains continues to be a concern because the program facilitates development in floodplains without mitigation for impacts on natural habitat values.

All U.S. West Coast salmon species, including 27 of the 28 species listed under the ESA, are negatively affected by an overall loss of floodplain habitat connectivity and complex channel habitat. The reduction and degradation of habitat has progressed over decades as flood control and wetland filling occurred to support agriculture, silviculture, or conversion of natural floodplains to urbanizing uses (e.g., residential and commercial development). Loss of habitat through conversion was identified among the factors for decline for most ESA-listed salmonids. Altering and hardening stream banks and wetlands, removing riparian vegetation, constricting channels and floodplains, and regulating flows have been identified as the primary causes of anadromous fish declines (USOFR 1999a, 2000).

On 14 April 2016, NMFS issued a biological opinion concluding that implementation of the NFIP in Oregon would jeopardize the continued existence of multiple species and adversely modify their critical habitat. NMFS provided a Reasonable and Prudent Alternative (RPA) to the proposed action. The RPA recommended several measures to reduce impacts of the NFIP, including improved floodplain mapping, mitigation for unavoidable impacts of floodplain development, and greater use of the Community Rating System to incentivize low-impact development.[11]

State permits for take of aquatic species

ODFW has been issuing permits and authorizations for the take of fish, shellfish, and marine invertebrates through a permitting program since as early as 1993. Take is defined under Oregon statutes as to “fish for, hunt, pursue, catch, capture or kill, or attempt to fish for, hunt, pursue, catch, capture or kill” (ORS 506.006, OAR 635-006-0001). Take of fish from the waters of the state is prohibited unless there is a permit or other authorization from ODFW in place to allow it (ORS 498.002, ORS 497.075).

ODFW’s permit program allows the agency to track take activities happening statewide and manage resources, including protections of listed or sensitive species or areas where sampling (or multiple sampling events) could have negative impacts. Permitting also allows ODFW to coordinate efforts so that researchers are not interfering or overlapping sampling areas, and ensures that researchers, educators, and restoration practitioners maintain compliance with laws and have protection from litigation. Approved permits and authorizations can include terms and conditions—such as sampling protocols, anesthetic guidelines, and temperature restrictions—which also promote responsible and ethical treatment of animals.

The permitting program authorizes the scientific, educational, and rescue/salvage take of all fish, shellfish, and marine invertebrates in Oregon. This responsibility arises from the authority assigned to ODFW and the Oregon Fish and Wildlife Commission in law (ORS 492.012, 497.075, 497.298, 498.002, 506.036, and 506.109; OAR 635-007-0900 to 635-007-0930, 635-100-0005, 635-100-0040, and 635-100-0125). A primary consideration in reviewing and authorizing permits is to assure the ethical and conservative use of these species, consistent with needs identified by the state list of threatened and endangered

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[11] In 1990, FEMA established the Community Rating System. Congress codified the program in the National Flood Insurance Reform Act of 1994. The program provides reductions in insurance premiums based on the extent to which a community’s floodplain management practices exceed the minimum NFIP requirements and provide for other flood damage reduction activities.

species (ORS 496.176 and 496.182), the sensitive species list (OAR 635-100-0040), conservation and recovery plans, and the Oregon Conservation Strategy (ODFW 2016). The ESA provides additional focus, and the program closely coordinates with NMFS and USFWS.

California Fish and Game Code (FGC) Sections 1002, 1002.5, and 1003 authorize CDFW to issue permits for the take or possession of wildlife, including mammals, birds and the nests and eggs thereof, reptiles, amphibians, fish, certain plants, and invertebrates for scientific, educational, and propagation purposes. CDFW currently implements this authority through Section 650, Title 14, California Code of Regulations (CCR), by issuing scientific collecting permits (SCPs) to take or possess wildlife for such purposes.

Research activities permitted by SCPs involving take and/or possession vary widely, including, but not limited to: baseline inventories; population assessments; environmental monitoring; studies of genetics, behavior, range, and distribution;diet and food chain interactions; and habitat relationships. Educational activities permitted by SCPs provide training and instruction opportunities to facilitate public understanding and appreciation of the state's natural resources, and foster future environmental scientists, wildlife biologists, and conservation stewards. Propagation activities permitted by SCPs promote efforts to increase wildlife numbers, enhance the sustainability and survival of species and populations, improve reproductive success, and/or contribute to educational programs. Results of permitted activities are reported back to CDFW, and contribute to the conservation and protection of fish and wildlife populations in California, helping inform management decisions.

Risk Factor 5: Other Natural or Man-Made Factors Affecting Its Continued Existence

Climate change

Climate change caused by past and ongoing global greenhouse gas emissions is a current threat to Pacific salmon, and is expected to become a larger threat over the next several decades (see Crozier and Siegel [2023] for a recent, comprehensive review). Globally, the years 2015–20 were the warmest on record, and 2023 is predicted to be among the top five warmest years on record (Climate at a Glance Global Time Series[12]). Rising temperatures and associated ecosystem changes are predicted to impact Pacific salmon by a variety of mechanisms throughout their life cycle (Crozier et al. 2008, 2019, Crozier and Siegel 2023). These impacts are complex and vary among species, ESUs, and habitats.

For U.S. West Coast salmon and steelhead, expected changes to freshwater habitats include increased air and stream temperatures and changes in seasonal (but not necessarily annual mean) rainfall patterns, with larger and more extreme storms and droughts. These increased temperatures will result in more winter precipitation falling as rain than snow at intermediate elevations, which alters both seasonal streamflow and water temperatures. In the OC and SONCC areas, stream temperatures are expected to rise, winter flows to increase, and summer flows to decrease compared to current patterns (ODFW 2021). For the OC

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[6] https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series/globe/land_ocean/ann/5/1850-2023

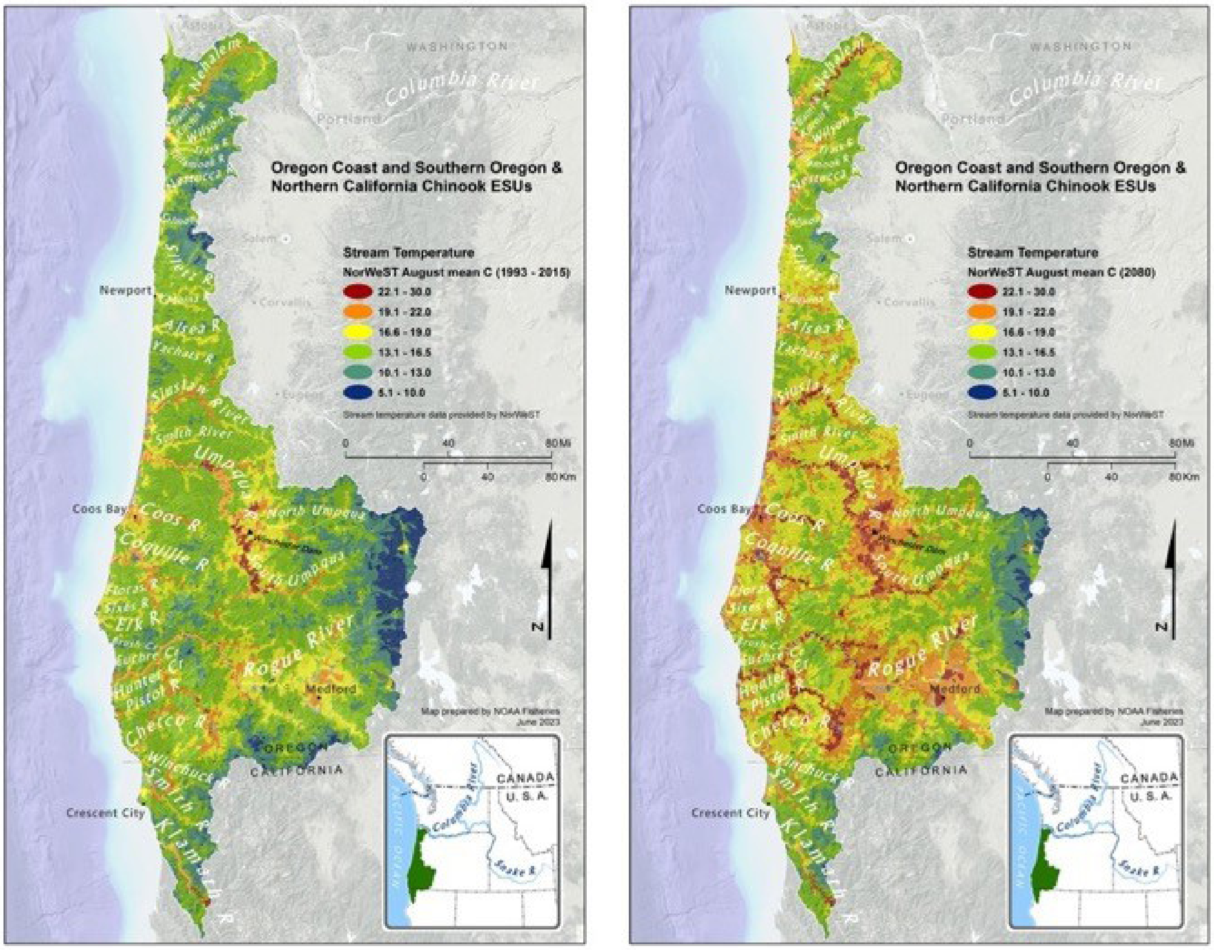

Figure 39. Average August stream temperatures estimated for the period of 1993–2015 (left) and predicted for 2080 (right). Data are from Isaak et al. (2017).

and SONCC Chinook salmon ESUs, the predicted effects of increasing temperatures may be particularly severe for the rivers that are already relatively warm during the summer, such as the Umpqua, Rogue and Coquille Rivers, and less so for others such as northern rivers of the Oregon coast and the Smith River in California (Figure 39). Substantial portions of the spawning and rearing areas in some rivers, including the Umpqua, Rogue, Nehalem and Coquille are predicted to have average August temperatures above 20°C (Figures 40 and 41), a point at which salmon are stressed physiologically and subject to greater disease pressures (Richter and Kolmes 2005). It is important to note, however, that these predictions are based on average stream temperatures for relatively large river reaches, and do not account for potential small-scale thermal refuges that salmon may use currently and in the future.

The effects of sea level rise are largely restricted to estuarine environments, but changes in water temperature, upwelling, currents, and ocean chemistry (acidification)—all of which influence productivity—are all expected in estuarine and ocean habitats. While these physical habitat changes are predicted with some confidence, their combined impacts on the food webs that support salmon in freshwater, estuarine, and marine habitats are much more difficult to predict, with uncertain impacts to salmon growth and survival.

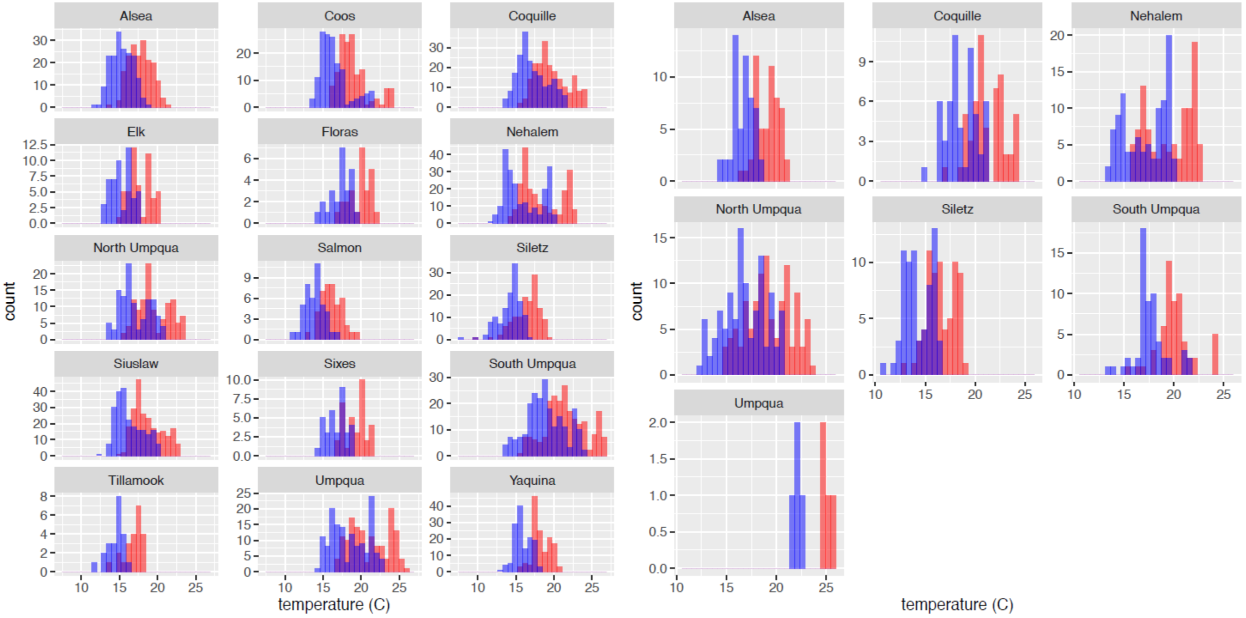

Figure 40. Distributions of average August stream temperatures estimated for the period of 1993–2015 (blue) and predicted for 2080 (red) for spawning and rearing reaches of fall (left) and spring (right) Chinook salmon in major OC rivers. Data are from Isaak et al. (2017).

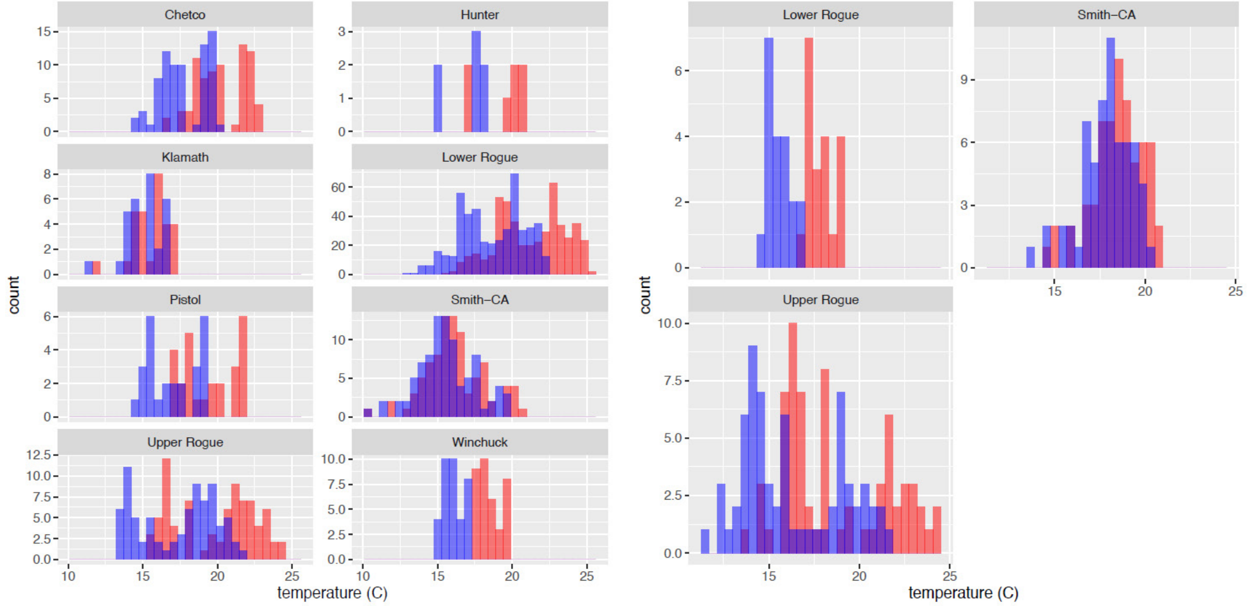

Figure 41. Distributions of average August stream temperatures estimated for the period of 1993–2015 (blue) and predicted for 2080 (red) for spawning and rearing reaches of fall (left) and spring (right) Chinook salmon in major SONCC rivers. Data are from Isaak et al. (2017).

In general, however, increased stream temperatures are expected to lead to lower egg-to-smolt survival rates, either directly through temperature-dependent mortality (in the case of fish that migrate in late summer) or indirectly through changes to flow patterns and increased sediment due to increased flooding. Temperature changes will also result in altered salmon developmental rates, which may lead to associated changes in timing of fry emergence and juvenile migration. Populations are likely to respond genetically and behaviorally to some of these changes, complicating detailed predictions of these effects. Climate change is also leading to major changes in the ocean ecosystem, including increasing ocean acidification, changes in the salmon prey base, and increasing marine heat waves such as “the Blob,” which dramatically affected U.S. West Coast salmon in 2014–16 (Bond et al. 2015, Peterson et al. 2017).

Climate change also appears to be affecting salmon in ways that were unanticipated only a few years ago. An example is the recent evidence of thiamine deficiency complex (TDC), a nutritional deficiency in thiamine (vitamin B1) that has been linked to high mortality of early life stages of Pacific salmon. Salmon fry experiencing TDC swim in a spiraling corkscrew pattern, exhibit lethargy (low ventilation rates and resting on lateral sides), and ultimately experience high mortality rates (Harder et al. 2018). These symptoms were first observed in hatchery populations of Chinook salmon in California’s Central Valley in 2020 (Mantua et al. 2021), but new evidence suggests that coastal populations of Chinook salmon, coho salmon, and steelhead in northern California have experienced TDC in the last several years (Mantua et al. in prep.).

Although the mechanisms causing TDC in fishes can vary, TDC in California Chinook salmon populations has been linked to changes in marine food webs in the southern half of the California Current Ecosystem, in particular the northern expansion and increased biomass of northern anchovy (*Engraulis mordax*), a prey species consumed by Chinook salmon. Anchovies contain high activity levels of thiaminase, a thiamine-degrading enzyme that has been linked with TDC in other species and ecosystems. Trawl data indicate that prior to 2018, anchovy-dominated trawls extended from southern California to San Francisco Bay; however, from 2019 to 2021, anchovy-dominated trawls have extended as far north as Cape Mendocino (Stierhoff et al. 2023). During this same period, biomass of anchovies off the central California coast has increased approximately ten-fold, and anchovies appear to have dominated the diets of Chinook salmon captured in ocean fisheries off the central California coast (Mantua et al. in prep.). Adult female salmon returning from the ocean produce eggs that are low in thiamine, with the emerging fry exhibiting symptoms of TDC.

Ongoing studies indicate that there has been an increase in the frequency of thiamine deficiency in salmonid eggs collected from northern California hatcheries. The percentage of family groups with eggs showing low or intermediate egg thiamine levels at Iron Gate and Trinity River Hatcheries increased from 2% in 2020 to 13–15% in 2021 for fall Chinook salmon. For coho salmon, the percentages increased from 3% in 2021 to 57–65% at these hatcheries over the same period. Steelhead from Trinity River Hatchery likewise showed an increase from 7% in 2020 to 18% in 2021. Interestingly, spring-run Chinook salmon eggs from Trinity River Hatchery did not show an increase (Mantua et al. in prep.). Collectively, the variability in frequency of TDC among species likely reflects differences in ocean rearing distributions, at least during some portion of their oceanic phase. Although there has been no demonstration of TDC in Chinook salmon from the OC or SONCC Chinook salmon ESUs, the substantial overlap in the marine distributions of Klamath River Chinook salmon and SONCC Chinook salmon suggests that TDC is a current and potentially growing threat for the latter ESU.

Climate vulnerability assessments

For the OC and SONCC areas, there have been several climate assessments focused on ESA-listed coho salmon (Stout et al. 2012, Wainwright and Weitkamp 2013, ODFW 2021) and at least one on other salmonids, including fall and spring Chinook salmon (Isaak et al. 2022). These assessments used predicted changes in seasonal stream temperature and flow through the end of the century based on downscaled global climate models to predict changes in freshwater habitat conditions for OC and SONCC salmonids. Isaak et al. (2022) highlighted the South Fork Umpqua River as likely to be particularly vulnerable to warming temperatures, since it already experiences near-lethal temperatures in some years and is expected to become 1–3°F warmer by the end of century. They concluded that other populations of OC and SONCC Chinook salmon may be less impacted by warming temperatures due to a relatively short juvenile freshwater life history and habitat use relatively low in the watersheds that may mitigate increasing high-flow events. They also noted that the regulation of water temperature by Lost Creek Dam is expected to mitigate climate effects related to temperate and flow for portions of the Upper Rogue River.

Subtle differences in habitat use and life-history characteristics for U.S. West Coast salmon and steelhead influence their vulnerability to climate impacts, with some being more (or less) exposed and/or able to adapt to their particular suite of climate effects. Consequently, it is necessary to know how sensitive, exposed, and therefore vulnerable to climate change a particular ESU is likely to be in order to fully evaluate whether a species is likely to become at risk of extinction in the foreseeable future.

Crozier et al. (2019) undertook a comprehensive climate vulnerability assessment for Pacific salmon and steelhead along the U.S. West Coast, focusing on ESUs that have received or are candidates for protection under the ESA. The assessment was based on three components of vulnerability: 1) biological sensitivity, a function of individual species characteristics; 2) climate exposure, a function of geographical location and projected future climate conditions; and 3) adaptive capacity, which describes the ability of an ESU to adapt to rapidly changing environmental conditions. Objectives were to characterize the relative degree of threat posed by each component of vulnerability across ESUs, and to describe landscape-level patterns in specific threats and cumulative vulnerability at the ESU level.

To accomplish these objectives, Crozier et al. (2019) evaluated a suite of freshwater, estuarine, and marine attributes that were predicted to be most limiting to salmon populations, using expected conditions at mid-century. For example, freshwater factors focused on high summer temperatures, flooding, drought, and changes in the hydrologic regime; estuaries were affected by sea level rise; and marine factors included temperature, upwelling and currents, and ocean acidification. They also evaluated stage-specific sensitivity to these expected changes, which relied largely on life-history attributes and ecological variation of populations within each ESU, and anthropogenic influences such as the production of hatchery fish and current listing status, which largely reflect historical anthropogenic influences.

Results of the assessment indicated that most U.S. West Coast salmon and steelhead ESUs had "high" exposure to these factors, due largely to high exposure to ocean acidification, and elevated sea-surface and stream temperatures. In contrast, sensitivity to these factors was highly variable, even though most listed Chinook salmon ESUs fell in the "high" or "very high" categories. ESUs at the southern end of the range or in interior basins, or those with limited life-history diversity, had the highest sensitivity scores. Chinook populations with subyearling life histories produced relatively low vulnerability scores during the *early life history* and *juvenile freshwater* stages, due to limited rearing in freshwater in summer, when thermal impacts, hydrologic regime shifts, and low-flow impacts are expected to be highest. However, some of these populations had high sensitivity to changes in estuarine conditions due to extensive rearing in these locations.

Neither the OC nor SONCC Chinook salmon ESUs were included in the Crozier et al. (2019) assessment. Here, we use results of the climate vulnerability assessment for listed ESUs that either had similar life histories or shared geographic ranges to conduct a climate vulnerability assessment for OC and SONCC Chinook salmon ESUs using the basic approach outlined by Crozier et al. (2019). Specifically, we used the assessments for the Lower Columbia River (LCR) and Coastal California (CCA) Chinook salmon ESUs to estimate likely sensitivity and exposure scores, because they share similar life-history patterns, inhabit rivers draining the western slopes of the Cascade and Coast Mountain Ranges, and were not too distant geographically. We also used two coho salmon ESUs (OC and SONCC) because—although their life histories are somewhat different—they inhabit the same geographic area as the ESUs in question. Clearly, a dedicated assessment using the expert teams employed by Crozier et al. to generate new scores would be useful, but this was beyond the scope of this evaluation.

Table 26 lists the life-stage and sensitivity scores for the four listed Chinook and coho salmon ESUs evaluated by Crozier et al. (2019), as well as our best estimate of how the factors would impact the OC and SONCC Chinook salmon ESUs. There is high overlap in factor and overall scores between all ESUs in the table, as we relied on the other ESUs to estimate the scores.

For *early life history, estuary*, and *adult freshwater* stages, all Chinook salmon ESUs had roughly overlapping river entry timing (spring and fall runs, except CCA Chinook salmon), fall spawn timing, limited freshwater residency (subyearling migrants, except some yearling migrants in LCR), and potentially extended residency in the larger estuaries. Consequently, we relied heavily on scores for the listed Chinook salmon ESUs and predicted low–moderate sensitivity for these attributes for the OC and SONCC Chinook salmon ESUs. However, because Rogue River Chinook salmon juveniles remain in freshwater and do not migrate to the ocean until July–September (Nicholas and Hankin 1989, ODFW 2007b), we gave higher scores for *juvenile freshwater* stage for SONCC Chinook salmon (high), slightly lower than the score for SONCC coho salmon (3.7 = high–very high), which spend an entire year in freshwater before outmigrating.

For the *marine* stage sensitivity, OC Chinook salmon have distributions similar to LCR (extending from local waters to southeastern Alaska; see earlier discussion), in contrast to CCA and SONCC Chinook salmon marine distributions, which are largely restricted to the California Current. In addition, their diets, length of ocean residency, and factors affecting mortality are expected to be comparable, and were thus scored similarly (low–moderate). We also ranked *cumulative life-cycle effects* following the evaluated Chinook and coho salmon

Table 26. Life-stage sensitivity, exposure, and overall vulnerability scores for Chinook and coho salmon ESUs evaluated by Crozier et al. (2019), and expected scores for OC and SONCC Chinook salmon ESUs. Numerical scores: 1 = low (L), 2 = moderate (M), 3 = high (H), 4 = very high (VH).

	Scores from Crozier et al. (2019)				**Expected scores**	
Category	**LCR Chinook (spr & fall)**	**CCA Chinook**	**SONCC coho**	**OC coho**	**OC Chinook**	**SONCC Chinook**
Early life history	1.3	1.7	2.5	1.8	L	L–M
Juvenile freshwater	1.5	2.3	3.7	3.1	L	H
Estuary	2.2	2.8	3.2	2.3	M	M
Marine	2.8	2.6	3.4	3.0	M	M
Adult freshwater	1.6	2.5	1.6	1.6	L–M	L–M
Cumulative life-cycle effects	1.3	3.3	3.3	2.1	L–M	M–H
Hatchery influence	3.3	1.1	2.2	1.3	L	L
Population viability	2.5	3	3.5	2.2	L–M	L–M
Other stressors	2.4	3.6	3.6	2.6	M	H
Sensitivity score	*Moderate*	*High*	*High*	*High*	*Moderate*	*High*
Stream temperature	3.4	3.3	3.7	3.2	H	H
Summer water deficit	2.3	2.4	2.7	2.7	M	M
Flooding	2.0	3.5	3.4	1.6	M	H
Hydrologic regime	2.4	1.0	1.4	1.3	L	L
Sea level rise	2.1	3.3	3.3	2.0	M	H
Sea surface temperature	3.4	3.3	3.3	2.8	H	H
Ocean acidification (OA)	1.9	1.8	1.8	1.9	L–M	L–M
OA exposure	3.8	4.0	4.0	3.9	VH	VH
Upwelling	2.3	3.3	2.9	1.7	M–H	M–H
Ocean currents	2.0	1.9	1.9	1.9	M	M
Exposure score	*High*	*High*	*High*	*High*	*High*	*High*
Overall vulnerability rank	**Moderate**	**High**	**High**	**High**	**Moderate**	**High**

ESUs, with a slightly lower score (low–moderate) for OC Chinook than SONCC Chinook (moderate–high), consistent with lower scores for northern (OC coho, LCR Chinook) versus southern (SONCC coho, CCA Chinook) ESUs evaluated by Crozier et al. (2019).

Hatchery influence in both the OC and SONCC Chinook salmon ESUs was expected to be low (comparable to the CCA Chinook and OC coho ESUs, but lower than LCR; see earlier text), and *population viability* was expected to score "low–moderate" (i.e., moderate–high viability) for both ESUs given the relatively large number of salmon returning each year despite high harvest rates. All four ESUs evaluated by Crozier et al. (2019) had moderate-to-high scores for *other stressors*, which include factors such as habitat loss and degradation, pathogens, invasive species, and toxins. Scores for this factor were slightly lower for LCR Chinook and OC coho salmon, which we used for OC Chinook (moderate), and higher for CCA Chinook and SONCC coho, which we applied to SONCC Chinook (high). The overall *sensitivity score* for the OC Chinook salmon ESU was moderate–high, intermediate between the LCR (moderate) and CCA Chinook salmon ESUs (high), respectively. SONCC Chinook salmon *sensitivity score* was high, similar to the CCA Chinook and the two coho salmon ESUs (all high).

For expected exposure scores, we relied on scores for listed OC and SONCC coho salmon ESUs, because of their shared common stream and estuarine habitats, although the details of how each species uses these habitats differ. Specifically, expected scores for *stream temperature, summer water deficit, flooding, hydrologic regime*, and *sea level rise* for the OC and SONCC coho salmon ESUs were applied directly to the two Chinook salmon ESUs. For ocean factors (*SST, ocean acidification (OA) and OA exposure, upwelling, ocean currents*), we relied on all four listed ESUs, which generally had similar scores. The resulting *exposure scores* for all six ESUs were high.

Our estimated *overall vulnerability* rank was moderate–high for the OC and high for the SONCC Chinook salmon ESUs. This places OC Chinook intermediate between other Chinook salmon ESUs, including the LCR (the least sensitive Chinook ESU evaluated) and Snake River fall, Puget Sound, CCA, and UCR spring Chinook. The vulnerability rating of high for SONCC Chinook salmon places it with the Snake River fall, Puget Sound, CCA, and UCR spring Chinook ESUs, and well below the Mid-Columbia River (MCR) spring, Upper Willamette, Central Valley (CV) fall/late fall, CV spring, and Sacramento winter-run Chinook salmon ESUs. This seems reasonable given the general trends in vulnerability of listed salmon ESUs based on their life-history traits and geographic location, in which interior and southern ESUs were more vulnerable than coastal ESUs (Crozier et al. 2019).

Recent trends in terrestrial and marine environments

Due to large-scale environmental variation captured by metrics such as the El Niño/Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), populations undergo periods of high and low productivity. Relatively productive conditions resulted in high freshwater and marine survival rates and subsequent high adult returns for many salmon stocks throughout the Pacific Northwest at various times, especially in the late 2000s and early 2010s. However, changes in ocean and freshwater conditions beginning in early 2014 due to exceptionally warm ocean waters and associated terrestrial impacts, plus an extremely strong El Niño event, led to subsequent declines in abundance in many populations. In the summer of 2021, a “heat dome” event led to record-breaking high temperatures throughout the Pacific Northwest. Here, we briefly summarize marine and terrestrial conditions over the past 20–25 years to provide environmental context when examining abundance and productivity trends for OC and SONCC Chinook salmon.

One important difference between Chinook salmon from the OC and SONCC ESUs is their use of marine waters. While both groups are largely restricted to the continental shelf, OC Chinook salmon migrate north and spend considerable time in coastal Britich Columbia and Alaska (Weitkamp 2010, Shelton et al. 2019). In contrast, SONCC Chinook salmon are largely restricted to the California Current. Because of these differences, coastal ecosystems used by SONCC Chinook salmon off the Washington, Oregon, and California coasts are just a small part of the area used by OC Chinook.

Terrestrial conditions

Annual average temperatures and precipitation by water year (October–September) provide a broad-brush view of terrestrial conditions across the Pacific Northwest. A strong and persistent warming trend and large year-to-year variations in precipitation are among the most notable features in recent decades (Figure 42). Within snow-dominated watersheds, warmer winters and springs experienced in recent years reduce snow accumulation and hasten snowmelt. Reduced snowpack causes an earlier and smaller freshet in spring and can result in lower minimum flows and higher stream temperatures in summer.

For the Pacific Northwest as a whole, including the Oregon and northern California coasts, water year 2015 stands out as the warmest year on record (Figure 42). The combination of below-average precipitation (Figure 43) and record-high surface air temperature in 2015

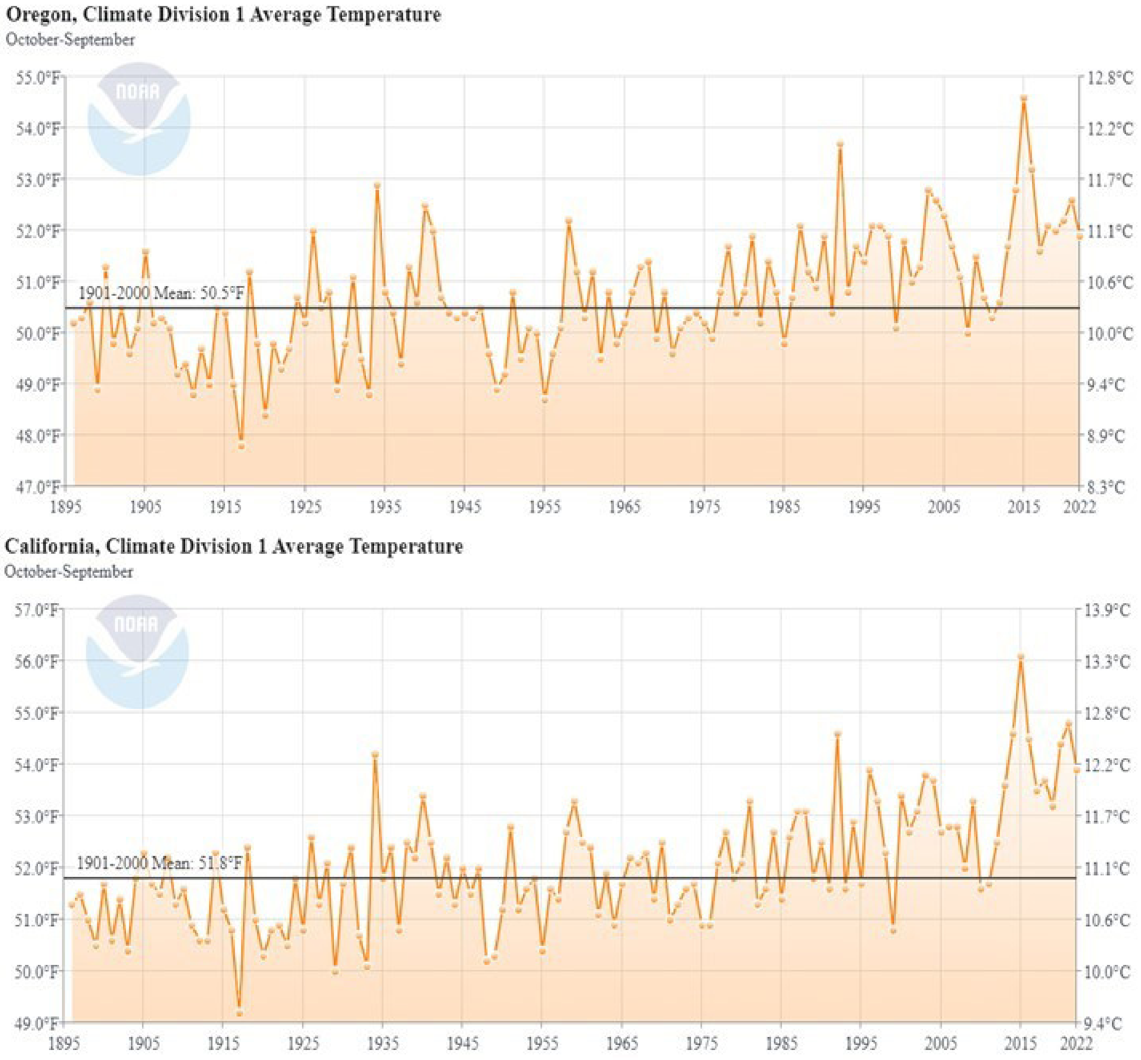

Figure 42. Water year (Oct–Sep) surface air temperature for the OR coast (top) and northern CA coast (bottom) regions. The historical average for 1901–2000 is shown with a black horizontal line. Data from https://www.ncdc.noaa.gov/ cag/divisional/time-series.

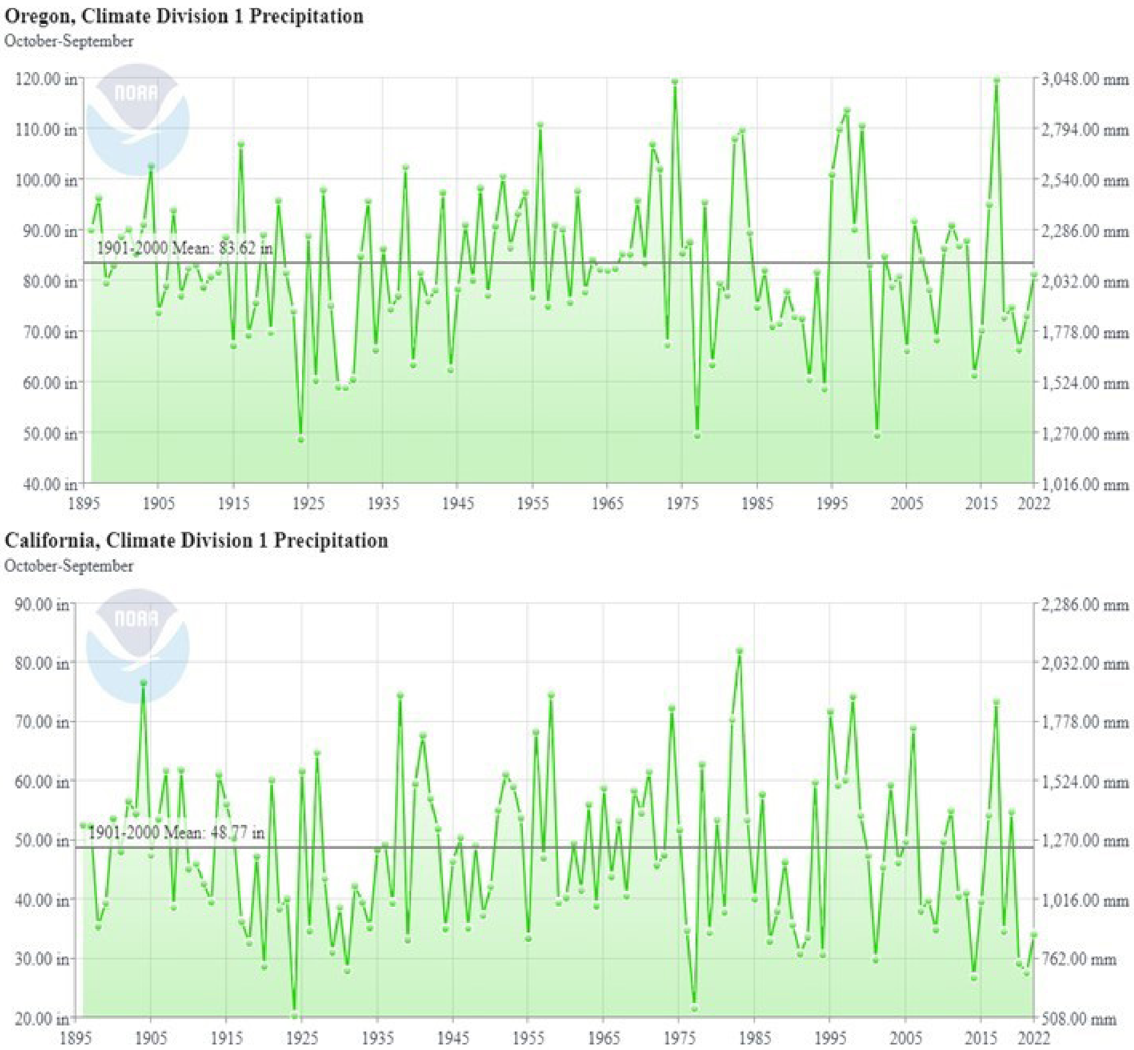

Figure 43. Water year (Oct–Sep) precipitation for the OR coast (top) and northern CA coast (bottom) regions. The historical average for 1901–2000 is shown with a black horizontal line. Data from https://www.ncdc.noaa.gov/ cag/divisional/time-series.

brought record-low springtime snowpack to much of the west. Diminished snowpack and high surface temperatures combined with low springtime precipitation yielded low and unusually warm runoff to western watersheds in spring and early summer 2015 (Figure 44).

From 25 June–2 July 2021, record-breaking terrestrial temperatures were recorded across western North America due to a heat dome (White et al. 2023). This 1,000-year event was caused by an exceptionally strong ridge centered over the area, whose strength was greatly increased by climate change. It resulted in some of the highest temperatures ever recorded across large parts of British Columbia, Oregon, and Washington (11–19°C/20–35°F above normal temperatures). Along the Oregon coast, maximum air temperatures during the heat dome in coastal towns (where air temperatures are recorded) were elevated (22.8–29.6°C/73–85°F), but coastal towns in southern Oregon and northern California (e.g., Brookings, Oregon; Crescent City and Eureka, California) were largely unaffected

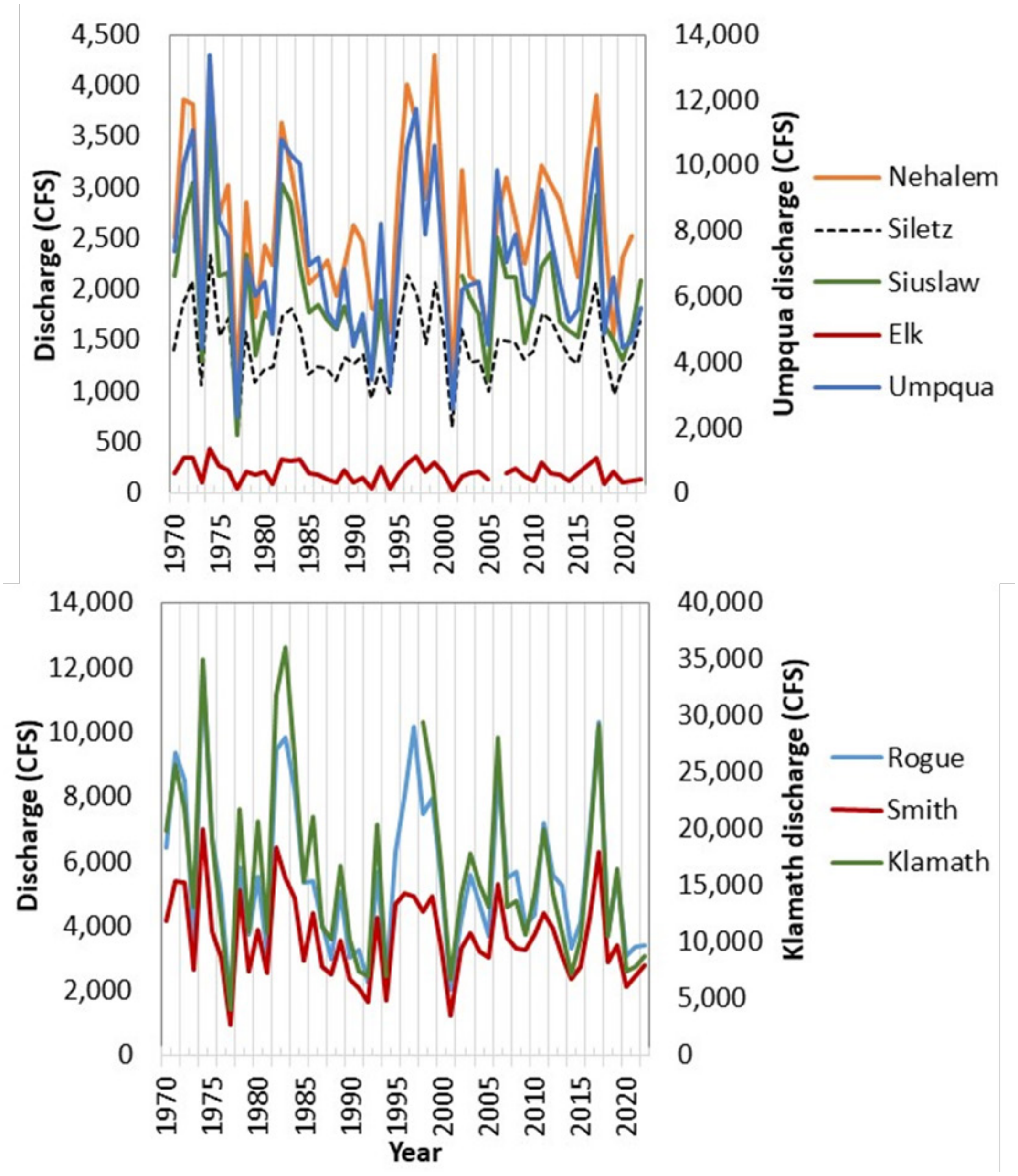

Figure 44. Annual streamflow by water year (Oct–Sep) during 1970–2022 for select basins in the OC (top) and SONCC (bottom) Chinook salmon ESUs. Note the Umpqua and Klamath River discharge is on the right vertical axis. Data from https://waterdata.usgs.gov. Station locations and numbers are: Nehalem near Foss, OR: 143010000; Siletz at Siletz, OR: 14305500; Siuslaw near Mapleton, OR: 14307620; Umpqua near Elkton, OR: 14321000; Rogue near Agness, OR: 14372300; Smith near Crescent City, CA: 11532500; Klamath near Klamath, CA: 11530500.

(<20°C/68°F).[13] These coastal temperatures were much cooler than what was observed in inland valleys (39–46°C/103–115°F; Ashland, Klamath Falls, and Medford, Oregon). Limited river temperature data suggest the heat dome also raised stream temperatures in some rivers. For example, maximum water temperature in Rogue River at Agness, Oregon (~RKM 29, USGS Station 14372300) increased by 5.1°C over six days (from 21.5°C on 19 June to 26.6°C on 27 June), although other rivers showed less increase over the same time period (e.g., only 1.0°C for the Klamath River near Klamath, California, USGS Station 11530500).

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[13] https://www.weather.gov/wrh/climate

The extent to which OC and SONCC Chinook salmon have been affected by elevated stream temperatures since 2015 is not known, but likely depends on fish behavior. Specifically, the freshwater residence time of juvenile OC and SONCC Chinook salmon varies from three to six months, with shorter/longer residency thought to be associated with warmer/colder river temperatures during the summer (Nicholas and Hankin 1988, Sparkman et al. 2016). Consequently, juveniles with "extended" freshwater rearing remain in freshwater through August or early September, and thus are likely most affected by elevated stream temperatures if they remain in rivers; these populations in Oregon include the Wilson, Trask, Nestucca, Siletz, Alsea, North Umpqua, Elk, Rogue, and Chetco Rivers. Those with "short" duration in freshwater have largely moved to the lower estuary or ocean by midsummer (July–August), and may escape the impacts (Salmon, Siuslaw, South Umpqua, Coos, and Sixes Rivers). For adult life stages, fall Chinook salmon typically re-enter freshwater one to several months after peak summer temperatures (Myers et al. 1998). However, spring Chinook salmon may have been impacted if they were in freshwater when the event happened and were unable to find cold refugia. Because of these life-history differences, the 2021 heat dome likely had the largest impacts on adult spring Chinook salmon in 2021, but will influence fall Chinook with extended freshwater residency starting in 2023 when they begin to return as adults.

California has also been prone to periods of extended drought, which result in decreased river flow and snow pack and elevated water temperatures. Recent strong droughts occurred in California during 2007–10, 2012–17, and 2020–22, when nearly 100% of the state had some level of drought (National Integrated Drought Information System).[14] Along the Oregon coast, these events were neither as severe nor as continuous as those in California.

Marine conditions

Sea surface temperatures (SSTs) in the northeastern Pacific Ocean vary on decadal time scales, with periods of above- and below-average temperatures, as indicated by the PDO (Mantua et al. 1997). Recently, SSTs in the northeastern Pacific were notably cooler than average (from 1999–2002, 2008–13, and again starting in 2020; Figure 45). They were warmer than normal from 2003–05, and at record highs for much of the period from fall 2013–20 due to a series of marine heatwaves (Figure 45). For the California Current region, SSTs reached record high levels from 2014–16, with 2015 being the single warmest year in the historical record (Jacox et al. 2018). In most years, positive PDO values correspond to El Niño events (e.g., the 2015–2016 El Niño), while negative PDO values correspond to La Niña events (e.g., 2021, 2022, and 2023 La Niñas).

Since the original warm Blob in 2014–16 (Bond et al. 2015), a series of marine heatwaves spread across large parts of the northern Pacific Ocean in 2019, 2020, 2022, and 2023 (California Current Marine Heat Wave Tracker).[15] These heatwaves not only cause elevated water temperatures, but are also associated with extremely low nutrient levels. The heatwaves vary greatly in their location across the North Pacific and, although largely offshore, occasionally spread to coastal waters such as in 2015 and occasionally since then (Figure 46).

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[14] https://www.drought.gov/

[15] https://www.integratedecosystemassessment.noaa.gov/regions/california-current/california-current-marine-heatwave-tracker-blobtracker

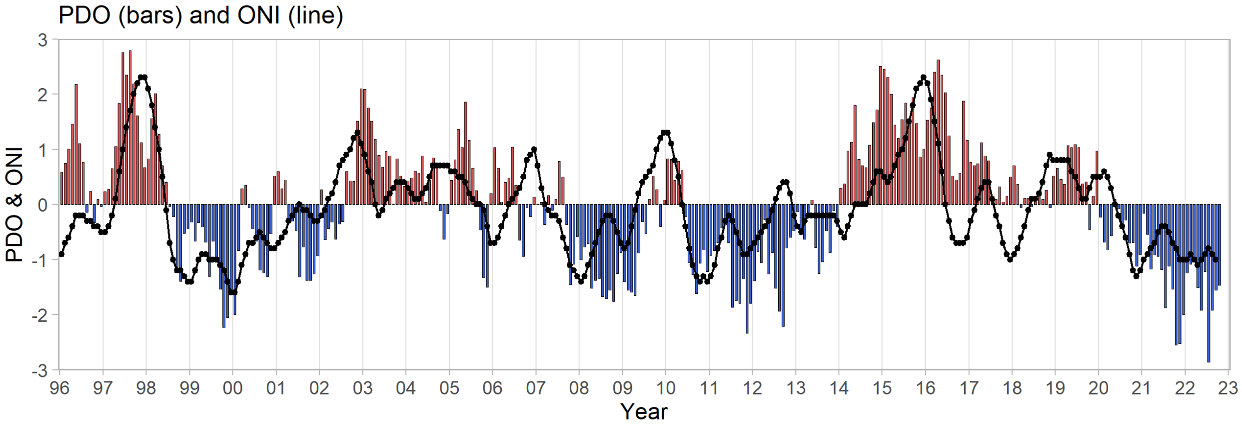

Figure 45. Time series of shifts in sign of the Pacific Decadal Oscillation (PDO; bars) and the Oceanic Niño Index (ONI; line) from 1996 to the present. Red bars indicate positive (warm) years; blue bars are negative (cool) years. Credit: NOAA Fisheries.

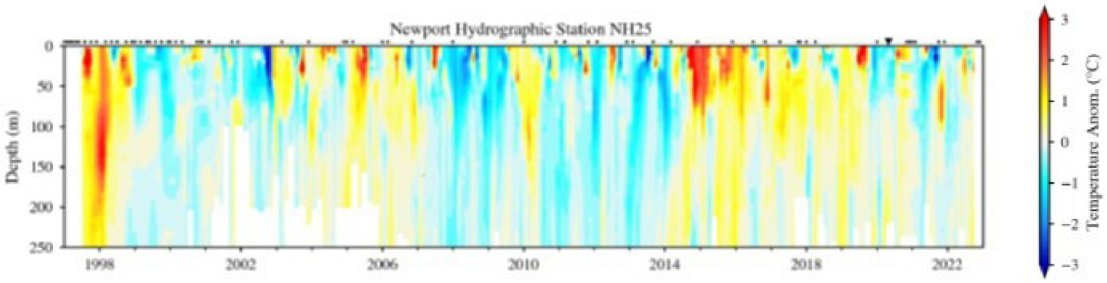

Figure 46. Time–depth temperature anomalies at Newport station NH25, 1997–2022. Figure from Harvey et al. (2023).

Biological impacts of marine conditions

The biological impacts of these temperature swings and marine heatwaves are documented in a number of annual reports[16] and descriptive papers (e.g., Morgan et al. 2019) for areas of the northeastern Pacific Ocean that Oregon and northern California Chinook salmon occupy during their marine residence period. In all cases, the reports show a dramatic biological response at all trophic levels—from primary producers to marine mammals and seabirds—to the marine heatwaves that have spread across the northeastern Pacific Ocean since 2014 and continued into 2023. These ecosystem changes have had large effects (both positive and negative) on Pacific salmon returns around the Pacific Rim.

Overall, the marine heat wave in 2014–16 had the most drastic impact on marine ecosystems in 2015, with lingering effects into 2016 and 2017. Conditions had somewhat returned to "normal" in 2018 and again in 2021, but marine heatwaves in coastal waters in 2019 and 2022 set off a series of marine ecosystem changes across the North Pacific.

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[16] The Integrated Ecosystem Assessment's California Current Ecosystem Status Report (https://www.integratedecosystemassessment.noaa.gov/regions/california-current); State of the California Current Report (e.g., Thompson et al. 2022); Fisheries and Oceans Canada's State of the Physical, Biological and Selected Fishery Resources of Pacific Canadian Marine Ecosystems (https://www.dfo-mpo.gc.ca/oceans/publications/index-eng.html); and Alaska Fisheries Science Center's Ecosystem Status Reports for the Gulf of Alaska, the Eastern Bering Sea, and the Aleutian Islands (https://www.fisheries.noaa.gov/alaska/ecosystems/ecosystem-status-reports-gulf-alaska-bering-sea-and-aleutian-islands).

Hatcheries

The effects of hatchery programs on the status of an ESU or DPS depend on which of the four key attributes—abundance, productivity, spatial structure, and diversity—are currently limiting the ESU/DPS, and how the presence of hatchery fish within the ESU/DPS affects each of the attributes (USOFR 2005). Research on the risks and benefits of hatcheries to natural salmon populations goes back decades, and has been the subject of numerous reviews (e.g., Hard et al. 1992, HSRG 2004, Mobrand et al. 2005, Araki et al. 2008, Naish et al. 2008, Kostow 2009, Anderson et al. 2020). In general, hatchery programs can potentially provide demographic benefits to salmon and steelhead, such as increases in abundance during periods of low natural abundance (e.g., Berejikian et al. 2008, Janowitz-Koch et al. 2019, Koch et al. 2022). Depending on how they are operated, they may also help preserve genetic resources until limiting factors can be addressed (e.g., Flagg et al. 1995, Kalinowski et al. 2012). However, these reviews have also concluded that long-term use of artificial propagation poses risks to natural productivity and diversity. Hatchery programs can affect naturally produced populations of salmon and steelhead in a variety of ways, including competition (for spawning sites and food) and predation effects, disease effects, genetic effects (e.g., domestication selection, or introgression due to stock transfers), and facility effects (e.g., water withdrawals, effluent discharge). The magnitude and type of risk depend on the status of affected populations and on specific practices in the hatchery program.

With the exception of the Elk and Salmon rivers, the fall-run spawning populations in both ESUs consist primarily of natural-origin spawners (Figures 12 and 22). Compared to other coastal Chinook salmon ESUs, such as the Lower Columbia River or Puget Sound, total hatcheries releases of fall-run Chinook salmon in the OC and SONCC ESUs are relatively low. The existing fall-run hatcheries stocks were founded locally, and regularly incorporate natural fish into their broodstocks, factors which further lessen their risk to natural populations (Ford 2002, Hess et al. 2012, Baskett and Waples 2013).

The situation with the spring-run hatcheries is more complex. As we discussed above in the ESU section, the spring-run hatcheries stocks released in the northern portion of the OC (Tillamook and Nestucca Rivers) have origins dating from the early-to-mid 20th century that likely involved use of broodstock from outside of the OC ESU. Few if any natural-origin fish are incorporated into the broodstocks (Table 1), and contemporary patterns of variation indicate that these stocks are distinct from natural OC salmon (spring and fall; Figure 6). All of these factors suggest that these stocks may pose genetic risks to native spring-run Chinook salmon that spawn in northern OC rivers. However, these hatchery stocks also are mostly homozygous for the early-run allele at the GREB1L region (K. O'Malley, personal communication), and any existing natural-origin spring-run Chinook salmon in the Tillamook and Nestucca Rivers may have already been influenced by these stocks.

In the Umpqua River, the genetic relationship between the spring run and the rest of the OC Chinook salmon ESU is complicated, but within the population, hatchery and natural fish appear to be genetically similar (see ESU Configuration). The small South Fork Umpqua River spring-run population has little hatchery influence, while the larger North Fork spring-run spawning population typically consists of ~50% hatchery-origin fish (pHOS; Figure 13). The hatchery (Rock Creek Hatchery) reportedly averages 18% natural-origin fish in its broodstock (pNOB; Table 1), for a proportionate natural influence (PNI = pNOB/(pNOS + pNOB) of 0.26. Guidelines developed for conservation hatcheries have recommended that PNI be >0.67 for conservation hatcheries in order to limit domestication selection (Mobrand et al. 2005, Paquet et al. 2011); based on these guidelines, the current hatchery program is likely posing some genetic risk to the North Fork Umpqua River spring-run population.

In the SONCC Chinook salmon ESU, the Cole Rivers Hatchery on the Rogue River is operated as a mitigation program to provide fishing opportunities for spring-run Chinook salmon (ODFW 2007b, 2016). The stock was founded locally, and is reported to use ~27% natural fish in the broodstock annually (ODFW 2016, p. 31). The proportion of hatchery fish on the spawning grounds is estimated to be very low—only 1.5% for the years 2016 and 2017 (ODFW 2007b), resulting in a PNI of 0.95, well above the Hatchery Scientific Review Group's (HSRG) recommendation of 0.67. Recently, ODFW has initiated a genetic monitoring program for both the hatchery and natural components of the Rogue River spring run, and found that the broodstock consisted mostly of fish homozygous for the "early" allele at the GREB1L region (84–88%, depending on the marker used; O'Malley 2020b). Based on its local origin, high PNI, and potential as an important reservoir for the spring-run allele, the Cole River Hatchery program may be providing a net conservation benefit to the SONCC Chinook salmon ESU. A potential concern, however, is that the existence of the hatchery could result in fishing pressure that is not sustainable by the natural population (ODFW 2007b, 2019a).

Risk Assessment

The team's determination of overall risk to the OC and SONCC Chinook salmon ESUs used the categories of "high risk" of extinction, "moderate risk" of extinction, or "low risk" of extinction. The high and moderate risk levels were defined in a prior review of OC coho salmon (Stout et al. 2012) and have also been used with minor wording changes for recent status updates of all listed salmon and steelhead ESUs (Ford 2022). They are defined as:

- **High risk:** A species or ESU with a high risk of extinction is at or near a level of abundance, productivity, diversity, and/or spatial structure that places its continued existence in question. The demographics of a species/ESU at such a high level of risk may be highly uncertain and strongly influenced by stochastic and/or depensatory processes. Similarly, a species/ESU may be at high risk of extinction if it faces clear and present threats (e.g., confinement to a small geographic area; imminent destruction, modification, or curtailment of its habitat; disease epidemic) that are likely to create such imminent demographic risks.
- **Moderate risk:** A species or ESU is at moderate risk of extinction if it exhibits a trajectory indicating that it is more likely than not to reach a high level of extinction risk in the foreseeable future. A species/ESU may be at moderate risk of extinction due to projected threats and/or declining trends in abundance, productivity, spatial structure, or diversity. The appropriate time horizon for evaluating whether a species or DPS is more likely than not to become at high risk in the future depends on various case- and species-specific factors. For example, the time horizon may reflect certain life-history characteristics (e.g., long generation time or late age-at-maturity), and may also reflect the timeframe or rate over which identified threats are likely to impact the biological status of the species or ESU (e.g., rate of disease spread). The appropriate time horizon is not limited to the period that status can be quantitatively modeled or predicted within predetermined limits of statistical confidence.
- **Low risk:** Neither at high or moderate risk of extinction.

The overall extinction risk determination reflected the informed professional judgment of each BRT member. This assessment was guided by the results of a "risk matrix" analysis, integrating information about demographic risks with expectations about likely interactions with threats and other factors. Following Stout et al. (2012), the team considered the foreseeable future as it relates to the moderate risk assessment to be a time period of 30–80 years. Beyond the 30–80-year time horizon, the projected effects on OC or SONCC Chinook salmon viability from climate change, ocean conditions, and trends in freshwater habitat become very difficult to predict with any certainty.

Risk matrix approach

In previous NMFS status reviews, review teams have used a risk matrix as a method to organize and summarize the professional judgment of a panel of knowledgeable scientists. This approach has been used for over 20 years in Pacific salmonid status reviews (e.g., Myers et al. 1998, Good et al. 2005, Hard et al. 2007), as well as in reviews of other marine species (e.g., Stout et al. 2001). In this risk matrix approach, the condition of individual populations within each ESU is summarized according to four demographic risk criteria: abundance, growth rate/productivity, spatial structure/connectivity, and diversity. These viability criteria, outlined in McElhany et al. (2000), reflect concepts that are well founded in conservation biology and are generally applicable to a wide variety of species. These criteria describe demographic risks that individually and collectively provide strong indicators of extinction risk.

In addition to these four demographic criteria, the team also considered the impacts of the environmental threats associated with the listing factors in ESA Section 4(a). These include habitat loss and degradation, over-utilization for commercial or scientific purposes, inadequate regulatory mechanisms, disease and predation, and risks associated with hatchery operations and climate change. The summary of demographic risks and environmental risks obtained by this approach was then considered by the SRT in determining the species' overall level of extinction risk.

Each of the demographic and environmental risk criteria for each population were evaluated by each team member against the following rubric:

- **Very low risk:** It is unlikely that this factor contributes significantly to risk of extinction, either by itself or in combination with other factors.
- **Low risk:** It is unlikely that this factor contributes significantly to risk of extinction by itself, but there is some concern that it may in combination with other factors.
- **Moderate risk:** This factor contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the near future.
- **High risk:** This factor contributes significantly to long-term risk of extinction and is likely to contribute to short-term risk of extinction in the foreseeable future.
- **Very high risk:** This factor by itself indicates danger of extinction in the near future.

In some cases, detailed information was not available at the population level, and in these cases, scores were provided at the level of the entire ESU. The scores were reviewed, and the range of perspectives was discussed by the team before making an overall risk determination. Although this process helps to integrate and summarize a large amount of diverse information, there is no simple way to translate the risk matrix scores directly into a determination of overall extinction risk. For example, an ESU with a single extant subpopulation might be at a high level of extinction risk because of high risk to spatial structure/connectivity, even if it exhibited low risk for the other demographic criteria. Another species might be at risk of extinction because of moderate risks to several demographic criteria.

After population-level risks were assessed, each team member assessed the risk (low, moderate, high) of each ESU as a whole. To allow individuals to express uncertainty in determining the overall level of extinction risk facing the species, the team adopted the "likelihood point" method, often referred to as the "FEMAT" method because it is a variation of a method used by scientific teams evaluating options under the Northwest Forest Plan (FEMAT 1993). In this approach, each SRT member distributes ten likelihood points among the three species extinction risk categories, reflecting their opinion of how likely that category correctly reflects the true species status. Thus, if a member were certain that the species is in the “low risk” category, that member could assign all ten points to that category. A reviewer with less certainty about the species’ status could split the points among two, or all three categories. This method has been used in most status reviews for anadromous Pacific salmonids since 1999, excluding five-year status updates for already-listed ESUs.

Assessing risk in a significant portion of each ESU’s range

In addition to assessing the risk status of each ESU as a whole, the team also evaluated whether there were *significant portions of the range* (SPR) of each ESU that are at either moderate or high risk of extinction. In doing this, the team followed advice from WCR and the NMFS Office of Protected Resources on how to interpret the phrase “significant portion of its range” in light of the 2014 joint USFWS and NOAA SPR policy (USOFR 2014) and subsequent legal rulings.

Based on this advice, our analysis involved identifying and evaluating portions of each ESU that are potentially at moderate or high risk of extinction and are important to the overall ESU’s long-term viability, yet not so important as to be determinative of its current or foreseeable status. In other words, the goal of the SPR evaluation was to determine if there are important portions of the ESU that are currently at high or moderate risk, but that are not so important that their status leads to the entire ESU being currently at high or moderate risk. The rationale for this approach is to ensure that there is a clear distinction between a species (or ESU) that is at risk throughout all of its range and one that is at risk in only a significant portion of its range.

The team considered and discussed several potential sub-ESU strata that would reasonably meet the criteria of being important to the ESU’s long-term viability but not so important that their status would drive current or foreseeable ESU-wide risk. After considering multiple possibilities, the team settled on a more detailed evaluation of two potential types of strata based on either geography or adult run timing. These are discussed in turn below.

Geographic strata

ODFW, in their Coastal Multi-Species Conservation and Management Plan (ODFW 2014), divides OC Chinook salmon into four geographic strata (Table 27). The same strata (along with a fifth, the “Lakes” stratum) were incorporated by NMFS into the OC coho salmon ESA recovery viability criteria (Wainwright et al. 2008). For OC coho salmon, all of these strata must be evaluated to be at low risk of extinction in order for the ESU as a whole to be considered at low risk of extinction in all or a significant portion of its range (Wainwright et al. 2008, NMFS 2016a). Recovery plans for other listed salmon ESU have identified similar geographic strata, and emphasized their importance in overall-ESU recovery goals (e.g., NMFS 2007, 2019c). Recovery criteria are not necessarily the same as listing criteria, but the team nonetheless concluded that, based on these precedents as well as the team’s independent evaluation, each stratum identified by ODFW (2014) and used in NMFS OC coho salmon recovery plans would be a significant portion of the range of OC Chinook salmon. Loss of any of these geographic strata would result in a substantial contraction of the range of the ESU and could therefore be reasonably inferred to negatively impact the ESU’s long-term viability.

Equivalent geographic strata for the SONCC Chinook salmon ESU as a whole have not been identified by state or tribal agencies, although ODFW has identified two fall Chinook salmon strata (Rogue River and coastal) for the Oregon portion of the ESU (ODFW 2013). The team, therefore, discussed and identified strata for this ESU based on analogy to the OC coho and Chinook salmon strata. Based on this evaluation, the team evaluated two possible SONCC geographic strata: the Rogue River as one stratum, and the coastal river systems (Hunter, Pistol, Chetco, Winchuck, Smith, and Lower Klamath Rivers; Figure 1) as a second stratum. The team was confident that the Rogue River is a significant portion of the range of the SONCC Chinook salmon ESU. A large majority of the annual spawning population in the ESU returns to the Rogue River, and the Rogue River watershed makes up a majority of the freshwater spawning and rearing habitat in the ESU. The team also concluded, with somewhat less confidence, that the coastal stratum was a significant portion of the range. This stratum typically contains about 20% of the total annual spawning abundance of the ESU, divided into several watersheds, each considerably smaller than the Rogue River. The existence of these populations, however, is likely important to the long-term viability of the SONCC Chinook salmon ESU, because a Rogue River-only ESU would clearly be more vulnerable to rare but catastrophic environmental events within the Rogue River. In addition, some of the coastal streams—in particular the Smith River and lower portions of the Klamath River—are predicted to remain much cooler than the Rogue River over the next 30–80 years based on future climate predictions (Figure 39), and may therefore provide important thermal refuges for the ESU in a warming climate.

Table 27. Geographic strata for OC Chinook salmon identified by ODFW (2014).

Stratum	Population/River
North Coast	Necanicum
	Nehalem
	Tillamook
	Nestucca
Mid Coast	Salmon
	Siletz
	Yaquina
	Alsea
	Yachats aggregate
	Siuslaw
Umpqua	Umpqua F
	N Umpqua S
	S Umpqua S
Mid-South Coast	Coos
	Coquille
	Flores
	Sixes
	Elk

Adult run-timing strata

The team also considered whether the variation in adult run timing might form the basis for identifying alternative strata. Variation in adult run timing and concerns about the status of the spring run were a major focus of the listing petition. Spring- and fall-run Chinook salmon utilize different freshwater habitats, particularly during the adult freshwater migration and spawning portions of the life cycle. As a general rule, spring-run Chinook salmon spawn in the upper portions of river systems, sometimes above flow barriers that are only accessible during high spring flows (reviewed by Quinn et al. 2016, Waples et al. 2022). In the larger Umpqua and Rogue River systems in the OC and SONCC ESUs, there is clear evidence for this type of spatial segregation. In the Umpqua River, for example, spring-run Chinook salmon spawn primarily in the North Fork, while fall-run (along with a much smaller number of spring-run) spawn primarily in the South Fork and the lower river (Figure 14). In the Rogue River, the spawning population above the old Gold Ray Dam site consists primarily of spring-run fish, while the lower river consists primarily of fall-run spawners (O'Malley 2020a). There is some evidence that the spatial segregation in the Rogue River between spring- and fall-run Chinook salmon was even more pronounced prior to construction of the Lost Creek Dam and its associated changes in flow regime (Thompson et al. 2019). Spatial segregation between spring- and fall-run Chinook salmon in the shorter coastal systems in each ESU is much less likely (reviewed by Myers et al. 1998), but there is some evidence of some spatial segregation in the Siletz River (Davis et al. 2017). In addition to this spatial and behavior separation, spring- and fall-run Chinook salmon are characterized by contrasting alleles of an ancient genetic polymorphism in a small region of chromosome 28 (Prince et al. 2017, Thompson et al. 2019, 2020, Waples et al. 2022).

After considering the current and historical distribution and status of spring-run Chinook salmon within each ESU, the team was unable to reach a consensus on whether the spring component within each ESU met the significance criteria of the SPR guidance. The team therefore elected to have each member independently evaluate whether the spring-run life history within each ESU was important to the long-term viability of the ESU, quantified using the likelihood point method.

For the OC Chinook salmon ESU, the team concluded that the spring run was not significant to the long-term viability of the ESU (average of 6.3 likelihood points out of 10 total points). Factors leading to higher weight on "not significant" included the lack of spring run-specific habitat in most of the river systems in the ESU, the lack of strong evidence that the spring run was ever historically a substantial component of the ESU, and the likelihood that the fall-run life history is more robust to predicted future climate changes in this ESU. Factors leading to some weight for concluding the spring run is significant to long-term ESU viability included uncertainty about future climate scenarios, the possibility that some, perhaps distant, future conditions might favor spring-run Chinook salmon, and the fact that the spring run occupies distinct freshwater (and possibly ocean, in the case of the Umpqua River) habitats and therefore provide a way for the ESU to spread its risk through time and space.

The team concluded that spring run Chinook salmon in the SONCC ESU were likely to be significant to the ESU's long-term viability (average of 5.7 likelihood points of 10 total). The team noted that the spring-run life history was a substantial component of the abundance of the Rogue River system, which is by far the largest in the ESU, both currently and historically. The spring-run life history is important for the ESU to fully access the habitat in the Rogue River, and might have also been historically important in the Smith River. Factors leading to some weight for the spring run not being important for long-term ESU viability were based primarily on the conclusion of most team members that it is at least plausible that the ESU could persist indefinitely in the absence of the spring run, and that adaptation of the ESU to future climate change seems likely to be more favorable for fall-run Chinook salmon.

Risk Results and Discussion

A summary of the risk matrix results is in provided in Table 28, and discussed in detail below.

Table 28. Summary of risk matrix results. *Avg* = average, *SD* = standard deviation of risk scores within the team, for each attribute of demography or threat. Scores = *1–5*, where *1* is very low risk (green) and *5* is very high risk (red; see text for definitions).

	Demography								**Threats**											
	Abundance		**Productivity**		**Spatial strc.**		**Diversity**		**Habitat**		**Over-utiliz.**		**Inadq. Reg.**		**Dis./pred.**		**Hatchery**		**Climate**	
Population	*avg*	*SD*	*avg*	*SD*	*avg*	*SD*	*avg*	*SD*	*avg*	*SD*	*avg*	*SD*	*avg*	*SD*	*avg*	*SD*	*avg*	*SD*	*avg*	*SD*
Nehalem	1.1	0.3	1.3	0.5	1.8	0.8	1.5	0.5	2.0	0.0	1.9	0.6	2.2	0.4	1.8	0.8	1.1	0.4	2.8	0.6
Tillamook	2.3	0.8	2.5	0.7	2.0	0.7	2.4	1.1	2.2	0.4	3.1	0.8	2.2	0.4	1.8	0.8	2.4	0.7	2.8	0.6
Nestucca	2.2	0.9	2.3	0.6	1.8	0.8	2.4	0.9	2.0	0.0	2.7	0.7	2.2	0.4	1.8	0.8	2.0	0.9	2.6	0.8
Salmon	1.8	0.6	1.3	0.5	2.0	0.7	2.3	0.7	2.2	0.4	2.3	0.9	2.2	0.4	1.8	0.8	3.1	0.6	2.5	0.7
Siletz	1.3	0.5	1.6	0.7	1.6	0.5	1.8	0.9	2.2	0.4	2.1	0.6	2.2	0.4	1.8	0.8	1.1	0.4	2.6	0.8
Yaquina	1.3	0.5	1.5	0.7	2.0	0.7	1.5	0.5	2.2	0.4	2.1	0.9	2.2	0.4	1.8	0.8	1.1	0.4	2.7	0.5
Alsea	1.0	0.0	1.3	0.5	1.8	0.4	1.9	0.8	2.0	0.0	1.9	0.6	2.2	0.4	1.8	0.8	1.3	0.5	2.8	0.6
Siuslaw	2.3	0.9	2.5	0.7	1.6	0.5	1.8	0.7	2.2	0.4	2.7	0.5	2.2	0.4	1.8	0.8	1.1	0.4	2.9	0.3
Umpqua F	1.2	0.4	2.1	0.3	2.0	0.7	1.3	0.5	2.2	0.4	2.2	0.4	2.2	0.4	2.0	0.7	1.3	0.5	2.7	0.5
N Umpqua S	1.9	0.7	2.2	0.8	2.4	0.7	2.5	1.1	2.6	0.5	2.2	0.4	2.4	0.9	2.0	0.7	3.1	0.6	3.7	0.5
S Umpqua S	3.6	0.7	2.6	0.9	2.5	0.9	2.9	0.8	2.8	0.8	2.3	0.5	2.4	0.9	2.0	0.7	1.4	0.7	3.8	0.6
Coos	1.5	0.5	1.8	0.6	2.0	0.7	2.1	0.6	2.2	0.4	2.1	0.6	2.2	0.4	1.8	0.8	2.3	0.5	2.7	0.5
Coquille	3.4	1.0	3.5	0.7	2.0	0.7	1.9	1.0	2.2	0.4	2.7	0.5	2.2	0.4	2.0	0.7	1.4	0.5	2.7	0.5
Flores	3.1	0.9	2.5	0.7	2.0	0.7	1.6	0.7	2.0	0.0	2.1	0.8	2.2	0.4	1.8	0.8	1.4	0.5	2.7	0.7
Sixes	1.8	0.6	1.5	0.7	2.0	0.7	1.4	0.5	2.0	0.0	2.0	0.7	2.2	0.4	1.8	0.8	1.4	0.5	2.6	0.5
Elk	2.1	0.7	2.1	0.9	2.0	0.7	2.4	0.7	1.8	0.4	2.3	0.9	2.2	0.4	1.8	0.8	2.8	0.8	2.5	0.7
OC ESU	1.6	0.6	2.1	0.2	1.6	0.6	2.0	0.4	2.2	0.4	2.2	0.5	2.4	0.5	1.8	0.4	1.7	0.4	2.9	0.4
Lower Rogue	1.5	0.5	1.8	0.6	1.6	0.5	1.3	0.5	2.4	0.5	2.3	0.5	2.0	0.0	2.4	0.5	1.3	0.7	2.9	0.7
Upper Rogue	1.5	0.7	2.3	0.5	2.3	0.5	2.6	1.0	3.0	0.9	2.3	0.5	2.2	0.4	2.6	0.9	2.6	0.7	3.6	0.5
Hunter	2.9	0.9	2.2	0.6	2.0	0.7	1.9	0.7	2.2	0.4	2.2	0.8	2.0	0.0	1.8	0.8	1.1	0.3	2.7	0.7
Pistol	2.5	1.1	2.1	0.6	1.8	0.8	1.7	0.8	2.2	0.4	2.2	0.8	2.0	0.0	1.8	0.8	1.1	0.3	2.7	0.7
Chetco	2.1	0.7	2.2	0.8	1.6	0.5	2.0	0.0	2.2	0.4	2.7	0.5	2.0	0.0	1.8	0.8	1.8	0.4	2.9	0.7
Winchuck	2.4	0.8	2.2	0.6	1.8	0.8	1.7	0.8	2.2	0.4	2.6	0.5	2.0	0.0	1.8	0.8	1.1	0.3	2.7	0.7
Smith	1.7	1.0	2.0	0.9	1.8	0.4	2.5	0.9	2.2	0.4	2.3	0.5	2.0	0.0	1.8	0.8	1.6	0.7	3.1	0.6
Blue Cr.	2.8	1.0	2.0	0.5	1.8	0.4	2.1	0.7	2.0	0.7	2.2	0.7	2.0	0.0	2.0	0.7	1.2	0.7	2.6	0.7
SONCC ESU	2.1	0.7	2.1	0.5	2.0	0.5	2.2	0.7	2.2	0.4	2.3	0.6	2.3	0.5	1.9	0.2	1.5	0.7	3.0	0.5

Color key:	1	2	3	4	5

OC Chinook salmon ESU: Rangewide assessment

The team concluded that the OC Chinook salmon ESU was most likely to be at low risk of extinction, with individual team members placing between six and nine (of 10) likelihood points into the low-risk category. Over all members, the average assessment was 7.0 for low risk, 2.8 for moderate risk, and 0.2 for high risk.

The primary factors leading to the conclusion of low extinction risk included relatively high total abundance, with multiple populations having natural-origin spawning abundance of >10,000 spawners in typical years, and total-ESU abundance commonly >100,000 spawners. The high total exploitation rates (commonly exceeding 50% for most populations), although a source of some concern to the team, were also cited as evidence of relatively high productivity, because the populations are (generally) maintaining their abundance despite high harvest rates. The team noted that the ESU consisted of numerous, well distributed spawning populations, and concluded there were few risks associated with spatial structure. The long-term, segregated spring-run hatchery programs in the Tillamook and Nestucca Rivers were considered a risk factor, as were several of the fall-run programs, but in general the relatively limited hatchery production in the ESU was not considered to be a substantial risk to diversity. Despite some concerns for the spring run (see further discussion below), the team also generally concluded that the ESU as a whole contained considerable life-history diversity.

In evaluating threats, most team members concluded that most current factors (habitat, overutilization, inadequate regulations, disease/predation, hatchery effects) currently presented low-to-moderate risk to the ESU. The team noted that there was a long history of land-use practices leading to habitat degradation, but that freshwater habitat has likely been improving slowly over the past several decades due to stricter land-use regulations compared to the early 20th century. The team noted that exploitation rates were quite high, but found that fishery management appeared to be at least somewhat responsive to changes in status, particularly for terminal fisheries. More distant ocean fisheries may be less responsive to local population status.

Potential effects of future predicted climate change are clearly a risk. The team was particularly concerned that rising stream temperatures and lower summer flows would be detrimental to the spring-run life history, since adults spend some or all of the summer in freshwater systems that are predicted to be exposed to higher temperatures, and the spring runs are already at low abundance in most of these rivers. Populations characterized by late-summer/early-fall smolt outmigration may also be more vulnerable than those with early-summer outmigration. The team also noted, however, that there remains considerable uncertainty about the localized effects of climate change to these populations, and that predicted future stream temperatures in many of the coastal streams remain within the healthy range for salmon.

Although generally confident that the ESU was at low risk, the team also put some weight on the possibility that the ESU was moderate or high risk (average of 2.8 for moderate, 0.2 for high). The rationale for putting some weight on high risk included the potential for catastrophic declines by the end of this century due to climate change (including associated increases in frequency of wildfires, floods, etc., during freshwater phases, and altered marine climate) or other difficult-to-predict, large-scale environmental changes. The rationale for putting some weight on moderate risk included concerns about the threat of climate change along with recent, largely unexplained, sharp declines in multiple populations. Most of the populations in the ESU have a pattern of cyclical changes in abundance (Figures 12 and 14) in which recovery from abundance troughs is common, but the team was concerned that the recent low abundances in some populations, including the Coquille, Tillamook and Nestucca Rivers, were particularly low compared to the typical abundance troughs over the past several decades.

OC Chinook salmon ESU: SPR assessment

The team evaluated the risk status of each of the four geographic strata (Table 27) and concluded, with varying degrees of confidence, that all were most likely to be at low risk of extinction. The Mid Coast, North Coast, and Umpqua strata had an average of 7.9, 7.0, and 6.9 likelihood points in the low-risk category, respectively. The team was less confident that the Mid-South Coast stratum was at low risk, with an average of 5.2 likelihood points in the low-risk category (4.8 in moderate risk). Concerns about the southern populations included generally lower and recently declining abundance, especially a sharp recent decline of the Coquille River population. Nonetheless, each of the four strata had at least one, and usually several, populations that the team considered to be abundant, productive, and at low risk of extinction.

Although the team concluded that the spring-run component of the OC Chinook salmon ESU was not significant to the ESU's long-term viability, we nonetheless evaluated the spring run's risk of extinction. The spring-run life history was considered to be at some risk, with a majority of likelihood points in either the moderate- (5.0) or high-risk (0.8) categories, with a minority (4.2) in the low-risk category. Risk factors for the spring run included concerns about its overall relatively low abundance in the ESU, the status of the very small South Fork Umpqua River population, negative effects of straying by the segregated hatchery programs in the Tillamook and Nestucca River systems, and high vulnerability to future climate change due to warming summer river temperatures, especially in the lower and south fork portions of the Umpqua River. Factors leading to weight on low risk included higher recent abundances in the Umpqua River system than were recorded in the mid-20th century, and increasing or roughly stable recent trends in some smaller river systems, such as the Siletz and Alsea Rivers. Some climate assessments (Isaak et al. 2022) have also predicted relatively cool future temperatures for the North Fork Umpqua River, which currently contains the bulk of the early-run spawners in the ESU.

SONCC Chinook salmon ESU: Rangewide assessment

For the SONCC Chinook salmon ESU, the majority of the likelihood points (5.5) were in the low-risk category, with 4.2 in moderate risk and 0.4 in high risk. Factors that contributed to the low-risk scores included overall high abundance, which has been commonly >50,000 natural spawners for the ESU as a whole, most of which consist of natural-origin fish. This high abundance has been maintained in the presence of relatively high total exploitation rates. Although there are clear concerns about the status of the spring-run component of the ESU (discussed below), the spring-run life history nonetheless remains present, with several thousand spawners annually in the Rogue River. The fall-run component is spatially spread across multiple populations, most of which typically have natural spawning abundance in the thousands. Environmental and regulatory risks were generally evaluated to be low, while climate risks were evaluated to be moderate.

Factors that contributed to moderate- or high-risk scores included the relatively small number of populations in the ESU, with the majority of the ESU's abundance concentrated in the Rogue River. There was also concern about a lack of accurate abundance information for some populations, especially for the Smith River in California. Exploitation rates were likely higher than optimal for these populations in some years, and the team was also concerned about the lack of any direct consideration of SONCC ESU status in setting ocean harvest rates. The sharp decline in Rogue River spring-run abundance that occurred circa 1990 without subsequent recovery (Figure 24) was also a concern. The effects of future climate change were also of considerable concern to the team, particularly for the spring-run life history whose habitat may be differentially vulnerable to high temperatures, lower summer flows, and the effects of increasing wildfires and associated disturbances.

SONCC Chinook salmon ESU: SPR assessment

In considering the geographic strata, the team concluded that the Rogue River stratum was at low risk (mean 6.6), with some weight also given to moderate risk (mean 3.4). A majority evaluated the coastal stratum to be at moderate risk (mean 5.2), with a minority for low risk (mean 4.7) and minor consideration for high risk (mean 0.1). For the coastal stratum, primary concerns were the relatively small sizes and small number of coastal populations, and a lack of adequate monitoring for the important Smith River population.

The team concluded that the spring-run life history in the SONCC was at risk, with a majority of likelihood points in either the moderate- (4.8) or high-risk (0.7) categories, and a minority (4.5) in the low-risk category. Risk factors for the spring run included the large decline in the Rogue River in the mid-1990s and lack of subsequent recovery, despite considerable ongoing conservation efforts (ODFW 2019a). Recent average abundance estimated at the former Gold Ray Dam site, for example, was 4,540 from 2019–21, below the 5,000-spawner threshold ODFW has identified as indicative of a significant deterioration in status (ODFW 2007b, p. 79) and a fraction of the typical abundance prior to 1990. Abundance in 2007 (3,465 natural spawners) was also below ODFW's single-year threshold for significantly deteriorating status. Other risk factors include the near lack of spring-run Chinook salmon outside of the Rogue River; the ongoing effects of the Lost Creek Dam, which may be increasing geneflow between the fall and spring runs in the Rogue River, with possible negative effects on the spring run; and the vulnerability of the spring run to the very high summer Rogue River temperatures that are predicted by the end of the century due to climate change.

Factors leading to some weight on low risk included a relatively stable abundance of spring-run Chinook salmon in the Rogue River since 2004, including multiple years with >10,000 natural spawners above the old Gold Ray Dam site—an abundance that is sufficiently high to avoid typical small population concerns. The team also noted that some recent climate assessments (ODFW 2014a, Isaak et al. 2022) have concluded that ongoing temperature and flow regulation by Lost Creek Dam is expected to mitigate some of the temperature increases predicted due to climate change in the portion of the Upper Rogue River that currently contains the bulk of the spring Chinook salmon spawning population.

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