# Petition to List the Washington Coast ESU of Spring-Run Chinook Salmon (*Oncorhynchus tshawytscha*) under the Endangered Species Act

Chehalis Spring-Run Chinook Salmon, Skookumchuck River

**Center for Biological Diversity**
**Pacific Rivers**
**July 17, 2023**

## Executive Summary

The Center for Biological Diversity and Pacific Rivers request the National Marine Fisheries Service to list an Evolutionary Significant Unit (ESU) of spring-run Chinook salmon (*Oncorhynchus tshawytscha*) on the Washington coast as an endangered or threatened species under the Endangered Species Act; or, in the alternative, list the Washington Coast ESU as presently defined (which includes both spring- and fall-run Chinook salmon) as an endangered or threatened species under the ESA, based primarily on spring-run salmon declines.

Spring-run Chinook salmon are arguably the most prized of all the Pacific salmon, playing a major role in the cultural, economic, and ecological fabric of the Pacific Northwest. Many genetically unique, locally adapted spring-run populations have already been extirpated across the range, and emaining populations are in serious jeopardy, including in the Washington Coast ESU. The combination of declining spring-run Chinook salmon across the range and new insights from genomic data has led to ESA-listing petitions in the Upper Klamath-Trinity Rivers, Southern Oregon/Northern California Coast, and Oregon Coast. In June of 2021 the California Department of Fish and Wildlife Commission unanimously voted to list Upper Klamath-Trinity spring-run Chinook under the state Endangered Species Act.

Like other salmonids, spring-run Chinook are anadromous, migrating from the ocean upstream to the freshwater streams of their birth to reproduce. They differ, however, from their fall-run counterparts in the timing of migration from from ocean to freshwater. Spring-run Chinook salmon enter freshwater streams in a relatively sexually immature state and migrate upstream in the spring. They hold through the summer in deep pools, and spawn in early fall. Washington Coast spring-run Chinook exhibit an ocean-type life-history, with juveniles migrating to the ocean during their first year of life, normally within three months after emerging from spawning gravels. Spring-run Chinook spend more than half of their lives in saltwater in the ocean. Washington Coast spring-run Chinook are known to migrate north in the Pacific close to shore, which makes them particularly susceptible to harvest in sport and commercial mix-stock fisheries along the Washington Coast, Canadian Coast and Southeast Alaska.

Washington coast spring-run Chinook are presently treated as part of a larger Washington coast Chinook ESU that also includes fall-run Chinook. This ESU configuration was based on the belief that run-timing variation in Chinook (i.e., the differences between the spring- and fall-run phenotypes) was evolutionarily plastic, but new genomic data has demonstrated critical evolutionarily differences between the two runs. More specifically, the genetic variation necessary for spring run-timing arose from a single evolutionary event long ago in the species' evolutionary history. In other words, spring-run Chinook have a unique evolutionary history, are distinct from fall-run salmon in the same watersheds, and if extirpated, are unlikely to re-evolve within a human relevant timeframe. Each river's spring-run Chinook population is distinguished by this genetically-determined capacity for early migration, coupled with a suite of additional traits that render each population closely adapted to its particular local environment. Thus, spring-run Chinook of the Washington coast form a distinct phenotype that qualifies as an ESU, distinct from fall-run Chinook by virtue of their adult migration life history.

This is not a new concept; Traditional Ecological Knowledge acquired by the peoples indigenous to the Olympic Peninsula over hundreds and thousands of years made distinctions and identified differences between spring-run and fall-run Chinook salmon.

Spring-run Chinook inhabit the Chehalis, Quinault, Queets, Hoh and Quillayute coastal river basins in Washington. They have unique habitat requirements for migration, spawning, juvenile rearing, and adult residence in the ocean. Suitable spawning habitat is in mainstem rivers and tributaries, and requires cold water, cool resting pools in which to hold, clean spawning gravels, and optimal dissolved oxygen levels, water velocities, and turbidity levels. Access to spawning habitat is threatened by migration barriers, dams, and water diversions. The presence of deep cold-water pools is essential to the survival of spring-run fish in particular. During upstream migration, adult Chinook are in a stressed condition due to their reliance on stored energy to complete their journey, leaving them highly susceptible to additional environmental stressors. During their ocean residence, adults need nutrient-rich, colder waters that are associated with high productivity and sufficient rates of salmonid growth and survival.

By the 1950s most Washington Coast spring-run populations were severely depleted due to a combination of habitat degradation and both in-river and ocean fisheries. A myriad of state reports have documented significant declines in spring-run numbers between the 1950s to the present, and trends show migration timing becoming later with loss of the early migrating fish. Research suggests that this is the result of increases in interbreeding with fall Chinook, due to dam construction, the elimination of natural barriers, and climate impacts. Washington Coast spring-run Chinook runs are now a very small fraction of their historical abundance. New genomic data indicates that there is likely an overestimation of the current Chehalis Basin population due to a spatial and temporal overlap of run timing with fall Chinook. The decline in the spring-run Chinook phenotype threatens the future prospects of the presently defined Washington Coast ESU that includes both spring- and fall-run fish, because, in addition to reducing overall population numbers, it robs the entire ESU of important heterozygous variation that makes it more resilient to changing environmental conditions and anthropogenic threats.

The annual total number of naturally spawned, wild spring-run Chinook adult spawners returning to Washington Coast rivers, specifically the Chehalis, Quinault, Queets, and Hoh river basins, has averaged about 3,200 fish from 2010-2020. In the Chehalis River basin, for example, which historically supported an estimated spawning run size of 27,000 spring-run Chinook, adult returns from 2011-2020 averaged 1,600 fish. Over the past decade, adult returns in the Hoh River basin averaged around 1,000 fish; in the Queets River basin around 500 fish; and in the Quinault River basin only around 100 fish.

Washington Coast spring-run Chinook face numerous threats. Dams, water diversions and migration barriers block suitable riverine habitat, impede migration, and reduce water quality and quantity. Legacy impacts and habitat degradation due to logging and roads reduces stream shade, increases stream temperature, increases fine sediment in streams, reduces levels of in-stream large wood, and alters watershed hydrology. One of the most significant threats is the decline in reproductive isolation of spring-run fish from their fall-run counterparts. Historical reproductive isolation has been diminished by dams, climate impacts that have resulted in changes to hydrology and water temperature, and the elimination of natural migration barriers that historically segregated the spring and fall- run Chinook phenotypes. Hatcheries and artificial propagation of Chinook salmon has an impact on wild spring-run Chinook through increasing competition and predation, transmitting diseases, and reducing the fitness and productivity of wild salmon populations through interbreeding and genetic introgression.

Climate change is already causing widespread declines in the quantity and quality of habitat for Washington Coast Chinook, with the melting of glaciers on the Olympic Peninsula, changes in precipitation patterns, lower summer stream flows, higher water temperatures, and reduction in food due to changing ocean conditions. Take of spring-run fish in ocean commercial and recreational fisheries is likely a significant threat, although no data are available to directly estimate ocean harvest rates on any wild population of spring-run Chinook salmon in coastal Washington. Other threats include: increased predation and increases in non-native species such as smallmouth bass; pollution; poor ocean conditions; in-river sport fisheries; and poaching.

Existing federal and state regulatory mechanisms have proven unable to protect and recover Washington coast spring-run Chinook and their habitat. Washington coast spring-run Chinook suffer from chronically low abundance and remain in just a few remnant populations. Spring-run fish have very specific habitat needs, and there are still numerous unaddressed threats to every Washington Coast spring Chinook run and their habitat. Endangered Species Act protection is required to prevent their extinction and implement necessary recovery actions.

## Notice of Petition

Janet Coit
Assistant Administrator for Fisheries
janet.coit@noaa.gov

Jennifer Quan
Regional Administrator
West Coast Regional Fisheries Office
jennifer.quan@noaa.gov

Petitioners Center for Biological Diversity and Pacific Rivers formally petition the National Marine Fisheries Service (NMFS) to list an “evolutionary significant unit” (“ESU”) of spring-run Chinook salmon (*Oncorhynchus tshawytscha*) on the Washington coast as an endangered or threatened species under the Endangered Species Act (“ESA”); or, in the alternative, list the Washington Coast ESU as presently defined (which includes both spring- and fall-run Chinook salmon) as an endangered or threatened species under the ESA, based primarily on spring-run declines.

The petitioners file this petition pursuant to § 553(e) of the Administrative Procedure Act (APA), 5 U.S.C. §§ 551-559 and § 1533(b)(3) of the Endangered Species Act, and 50 C.F.R. part 424.14. The APA and the ESA grant interested parties the right to petition for issuance of a rule, and specifically to seek reconsideration of a prior determination where new information would lead a reasonable person conducting an impartial scientific review to conclude that delineation of a new ESU, Washington Coast spring-run Chinook salmon, and listing under the ESA is warranted.

Petitioners request that NMFS initiate a status review of the spring-run Washington Coast ESU of Chinook, in coastal basins north of the mouth of the Columbia River and southwest of the Lyre River in Washington. Petitioners request that NMFS independently evaluate listing the spring-run Washington Coast Chinook, which is currently included in the Washington Coast Chinook ESU, for ESA listing as an ESU separate from the fall-run component of the ESU. Alternatively, NMFS should evaluate listing of the entire Washington Coast ESU as presently defined.

A status review is warranted based on new information, in particular: better understanding of the genetics and phylogeny of early adult Chinook migration; effects of climate change on streamflow and water temperature; implications of a proposed dam on the Chehalis River; lack of regulatory measures for ocean harvest of depressed spring-run stocks from sport, mix stock and trawl fisheries; lack of sufficient genetic monitoring information; failure of regulatory mechanisms to ensure effective conservation of spring-run Chinook; recent spawning escapement and catch data for these populations that show long term declines; and possible over-estimations of population numbers in the Chehalis Basin.

Petitioners also request that NMFS designate critical habitat for spring-run Washington Coast Chinook concurrent with listing. Critical habitat should encompass all known and potential freshwater spawning and rearing areas, migratory routes, estuarine habitats, riparian areas, and essential near-shore ocean habitats.

Contact information for the petitioners:

Center for Biological Diversity
Jeff Miller, Senior Conservation Advocate
P.O. Box 11374
Portland, OR 97211-0374

jmiller@biologicaldiversity.org

Pacific Rivers
Michael Morrison, Board Chair
1001 SE Water Ave., Suite 450
Portland, OR 97214
info@pacificrivers.org

## Definitions and Abbreviations

Definitions of Run Timing Groups in Washington Coast Chinook Salmon:

Spring-run Chinook salmon in coastal Washington enter freshwater streams during spring (March through June) while still relatively sexually immature and mature in freshwater before spawning in late summer through early fall. Spring-run adults migrate high into watersheds, arrive near their eventual spawning grounds, and then hold over the summer in a fasted state in deep freshwater pools to allow their gonads to develop before spawning in late summer to early fall. Most of their offspring migrate to the ocean after spending only a few months in freshwater (i.e., an ocean-type juvenile life history). Spring-run Chinook salmon are also called "early" migrators because they enter rivers many months prior to spawning.

Fall-run Chinook salmon in Coastal Washington also display an ocean-type juvenile life history, but in contrast with spring-run Chinook, enter freshwater in late summer through fall (September through November) in a relatively sexually mature state and spawn shortly thereafter from October through January. Fall-run Chinook salmon are also called "late" migrators because they enter rivers shortly before spawning.

In Washington coastal rivers, Chinook referred to as summer-run are those that enter rivers from late June to the end of August. Summer-run Chinook generally display an intermediate distribution in run timing and spawning locations between the earlier migrating spring-run Chinook and the later migrating fall-run Chinook. The best available genetic evidence indicates that, in general, summer-run Chinook in coastal Washington rivers are the product of interbreeding between spring-run and fall-run Chinook salmon.

Since the early 1980s (and as spring-run fish continued to decline in relative abundance), biologists and fishery managers on the Washington coast have usually grouped spring- and summer-run Chinook salmon together, calling them simply spring-run or spring/summer-run fish, referring to all adult Chinook that start entering the rivers as early as March and continuing through the end of August. This convention was adopted before recent advances were made in the understanding of the genetic basis for Chinook run timing, which is determined by specific alleles in one small genomic region.

Genetic variation is relevant to both the naming conventions for Chinook salmon run types and their status. For the purposes of this petition, unless otherwise noted, the term "spring-run Chinook salmon" refers to fish that are homozygous (having the same alleles at a particular genetic locus) for the "early" allele at the GREB1L/ROCK1 locus (i.e., "homozygous early"; Waples et al. 2022); "fall-run Chinook salmon" refers to fish that are homozygous for the "late" allele at GREB1L/ROCK1 (i.e., "homozygous late"); and "summer-run Chinook salmon" refers to fish that are heterozygous, having one early and one late allele at GREB1L/ROCK1 (i.e., "heterozygotes").

## Abbreviations

ACS - Aquatic Conservation Strategy
APA - Administrative Procedure Act
CU – Conservation Unit
CWA – Clean Water Act
EDT - Ecosystem Diagnosis and Treatment
EPA - Environmental Protection Agency
ESA - Endangered Species Act
ESU - Evolutionary Significant Unit
FERC - Federal Energy Regulatory Commission
HCP – Habitat Conservation Plan
LRMP - Land and Resource Management Plan
NEPA - National Environmental Policy Act
NFMA - National Forest Management Act
NFP - Northwest Forest Plan
NMFS - National Marine Fisheries Service
NWIFC - Northwest Indian Fisheries Commission
OESF - Olympic Experimental State Forest
ONP – Olympic National Park
PFMC - Pacific Fishery Management Council
PMFC - Pacific Marine Fisheries Commission
QIN - Quinault Indian Nation
TEK - Traditional Ecological Knowledge
TMDL - Total Maximum Daily Load
USFS - U.S. Forest Service
USFWS – U.S. Fish and Wildlife Service
WCSSP - Washington Coast Sustainable Salmon Partnership
WDFW - Washington Department of Fish and Wildlife
WDNR - Washington Department of Natural Resources
WFPA - Washington Forest Practices Act
WRIA - Water Resource Inventory Area

## Table of Contents

# I. Introduction and Basis for Petition

## A. Legal Background

### 1. Definition of Evolutionary Significant Unit (ESU)

The Endangered Species Act defines "species" to include "any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." 16 U.S.C. § 1533(16); *see also Cal. State Grange v. Nat'l Marine Fish Serv.*, 620 F. Supp. 2d 1111, 1121 (E.D. Cal. 2008). The ESA does not define the term "distinct population segment." *Id*. at 1121.

In 1991 the National Marine Fisheries Service promulgated its "Policy on Applying the Definition of Species Under the Endangered Species Act to Pacific Salmon" or "Evolutionarily Significant Unit (ESU) Policy." 56 Fed. Reg. 58,612 (Nov. 20, 1991). The ESU Policy provides that a population (or particular collection of populations) of Pacific salmonids is considered to be an ESU, and therefore considered for listing under the ESA, if it meets the following two criteria: 1) the population must be substantially reproductively isolated from other nonspecific population units; and 2) the population must represent an important component in the evolutionary legacy of the species. Isolation does not have to be absolute, but it must be strong enough to permit evolutionarily important differences to accrue and to be evolutionarily maintained in different population units. The second criterion is met if the population contributes substantially to the ecological and/or genetic diversity of the species as a whole (Waples 1991). *See also Grange v. NMFS*, 620 F. Supp. 2d at 1123-24. That is, the loss of the population(s) would constitute a material diminishment of the ecological or genetic diversity of the species as a whole.

NMFS putatively considers all available lines of evidence in applying those criteria, specifically including data from DNA or genomic analyses ("data from protein electrophoresis or DNA analysis can be very useful because they reflect levels of gene flow that have occurred over evolutionary time scales"). ESU Policy, 56 Fed. Reg. at 58,518; see also: Definition of "Species" Under the Endangered Species Act: Application for Pacific Salmon, NOAA Tech Memo NMFS F/NWC-194 (Waples 1991) at page 8 ("The existence of substantial electrophoretic or DNA differences from other conspecific populations would strongly suggest that evolutionarily important, adaptive differences also exist."). The ESU Policy is an interpretation by NMFS of what constitutes an ESA-listable "distinct population segment" (DPS), and is a "permissible agency construction of the ESA." *Grange v. NMFS*, 620 F. Supp. 2d at 1124 (citing *Alsea Valley Alliance v. Evans*, 161 F. Supp 2d 1154, 1161 (D. Or. 2001)).

### 2. Criteria for Listing a Species Under the Endangered Species Act

The Endangered Species Act requires that NMFS protect imperiled species by listing them as either "endangered" or "threatened." 16 U.S.C. § 1533(a)(1). An "endangered" species is one "in danger of extinction throughout all or a significant portion of its range." 16 U.S.C. § 1532(6). A "threatened" species is "likely to become an endangered species within the foreseeable future." *Id*. § 1532(20).

When determining whether a species or subspecies, including an ESU, is endangered or threatened, NMFS must assess threats to the species based on five factors:

i. The present or threatened destruction, modification, or curtailment of its habitat or range;

- **ii.** Overutilization for commercial, recreational, scientific, or educational purposes;
- **iii.** Disease or predation;
- **iv.** The inadequacy of existing regulatory mechanisms; or
- **v.** Other natural or manmade factors affecting its continued existence. 16 U.S.C. § 1533(a)(l).

NMFS must list a species if it meets the definition of "endangered" or "threatened" due to any one or a combination of these five listing factors. 50 C.F.R. § 424.11(c); *see* 16 U.S.C. § 1533(a)(1).

## B. New Genomic Data Show that Spring Chinook Are Reproductively Isolated and Uniquely Important to the Evolutionary Legacy of the Species

### 1. Background

Throughout the historic range of spring-run Chinook, severe declines and extirpation have been apparent and clearly documented for decades. Starting in 2017, a series of studies began using new "genomic" technologies to investigate the genetic and evolutionary basis of spring run-timing. In early 2020, a group of scientists from federal and state agencies, universities, and tribal entities convened a workshop to review and synthesize these new data. The scientists produced an extensive review paper entitled "Implications of Large-Effect Loci for Conservation: A Review and Case Study with Pacific Salmon" (Waples et al. 2022). Rather than referencing each individual study, the following section will primarily reference this review paper because it represents the scientific consensus and thus the "best available science" on this topic.

### 2. Prior Model for Spring-Run Evolution and Basis for Current ESU Structure

Starting in the 1970s, various genetic studies found that in most coastal (i.e., non-interior Columbia) locations, spring- and fall-run Chinook from the same watershed are more similar to each other than to the same run-type from a different watershed. These patterns of genetic similarity were based on measurements of overall genetic differentiation and interpreted to suggest that run-timing differences had evolved independently many times. Therefore, it was believed that run-timing differences were evolutionarily plastic, and if spring run-timing were lost from a location, it could rapidly re-evolve from fall-run individuals in that location. Consequently, spring- and fall-run Chinook salmon have been considered part of the same ESU in most coastal locations. This evolutionary model and the resulting ESU configurations are consistent with the idea that run-timing differences are polygenic (i.e., controlled by many genes throughout the genome). This is discussed by Waples et al. (2022):

> "A series of large-scale studies of North American Chinook salmon have included both early- and late-returning fish from the same set of watersheds (Table 1). In coastal drainages and in the lower Columbia River, the following pattern has consistently been found: different life-history types of Chinook salmon and steelhead within the same stream are genetically more similar to each other than either is to the same life-history type in another stream (Figure 3)….
>
> Based on the genetic and life-history data described above, it was concluded that adult migration differences had evolved independently many times within both Chinook salmon and steelhead (Thorgaard 1983; Busby et al. 1996; Myers et al. 1998; Waples et al. 2004). Furthermore, it was thought that the early-migration phenotype could evolve from late-migrators on relatively short timescales (perhaps around 100 years; Waples et al. 2004). Therefore, in defining ESUs of coastal and

> lower Columbia River populations in both species, it was concluded that adult migration differences reflected diversity within ESUs (as illustrated in Figure 3)….
>
> These ESU configurations are consistent with the conventional paradigm that most quantitative genetic traits are due to many genes of small effect (Falconer and Mackay 1996; Mackay et al. 2009). Many studies support this paradigm; for example, height in humans is associated with many thousands of SNPs spread throughout the genome (Wood et al. 2014)."

### 3. New Insights from Genomic Data

Recent genomic data have upended the previous model for the genetic and evolutionary basis of spring run-timing in Chinook. This is discussed throughout Waples et al. (2022):

> "Several studies have reported that a single genomic region has a strong statistical association with adult migration timing in steelhead (Hess et al. 2016; Prince et al. 2017; Micheletti et al. 2018; Collins et al. 2020; Willis et al. 2020) and Chinook salmon (Prince et al. 2017; Narum et al. 2018; Thompson et al. 2019a, 2019b; Koch and Narum 2020, Thompson et al. 2020; Willis et al. 2021). These studies have identified one approximately 200 Kb region of chromosome 28, centered on the regulatory region between 2 genes called GREB1L and ROCK1 and containing part of the coding region of each gene (Figure 6). The strong association between this region and various measures of adult-migration phenotypes has been found in multiple populations of both species, from coastal California and Oregon, to the interior Columbia River, the Strait of Juan de Fuca, and Puget Sound (Supplementary Tables S1 and S2)….
>
> The evolutionary history of the GREB1L/ROCK1 region is complex and has not been well characterized throughout each species' entire range. But it is clear that the early and late haplotypes evolved long ago in each species' evolutionary history (Prince et al. 2017; Thompson et al. 2020). Based on available data, it is also clear that allelic variants for early migration have not arisen independently via new mutations from the genomic background of late migration individuals in each watershed….
>
> Discovery that specific alleles in one genomic region are associated with the early-run trait implies that the trait is at greater risk than if it were highly polygenic, because loss of the "early" allele(s) equates to loss of the phenotype. If early allele(s) were recessive, a genetic reservoir might persist in late-run populations, but that does not appear to be the case. Available evidence indicates that early allele(s) are codominant or partially dominant, and surveys in multiple Chinook salmon populations indicate that early alleles disappear or become extremely rare after extirpation of the early phenotype. This indicates that, although hatchery propagation might be an important conservation strategy and source of early-run alleles in the short term, the only reliable way to conserve early-run genes in nature is by maintaining habitat that supports early-run phenotypes."

The important conservation implications of these new genomic findings are clearly acknowledged throughout Waples et al. (2022):

> "Recent findings—in both steelhead and Chinook salmon—of strong associations between specific alleles and adult migration timing pose the following questions: 1) Should existing conservation units be reconfigured in response to these new data? 2) Should methods for viability assessment be modified (and if so, how)? 3) Should new/different conservation measures be implemented to ensure persistence of important components of biodiversity?"

### C. Basis for Listing Washington Coast Spring Chinook as a Separate ESU

As described above, the ESU policy requires two criteria be met for spring-run Washington Coast Chinook to qualify as a separate ESU from their fall-run counterparts. The first criterion is substantial reproductive isolation. In this context, as described in the ESU policy, substantial does not mean that the reproductive isolation needs to be complete (or even nearly complete) but instead that the reproductive isolation needs only to be sufficient for important evolutionary differences to accrue and be maintained. As discussed in the previous section (and further below), the science clearly shows that the genomic differences between spring- and fall-run Chinook are important from an evolutionary perspective. Therefore, to determine if spring-run Washington Coast Chinook qualify as a separate ESU, the question becomes what if any role does reproductive isolation play in its accrual and maintenance. The answer to this question is discussed throughout Waples et al. (2022):

> "The early-migration strategy entails several costs, including foregone opportunity for growth in the ocean, and exposure to predation, pathogens, and extreme temperature and flow regimes in freshwater habitats where they hold while fasting prior to spawning (Quinn et al. 2016). Because the early-migration strategy is nevertheless widespread, it must generate benefits to offset these costs. Several potential benefits have been identified, but for Pacific salmonids it is generally thought that the crucial factor is access to specific spawning and rearing habitats that temperature/flow conditions make unavailable (or less available) to later-migrating fish (Quinn et al. 2016)….
>
> Where flow-dependent and/or thermal migration barriers have been removed or their temporal passage windows altered (e.g., falls are laddered or cascades altered), early-migrating populations can be displaced by their late-migrating counterparts (Hemstrom et al. 2018; Thompson et al. 2019a). Flow regulation by dams also can affect adult migration timing. Changes to downstream flow and temperature conditions are thought to have selected against spring-run Chinook salmon in the Rogue River by allowing for expansion of the fall-run Chinook salmon distribution into habitat that was previously accessible primarily by spring-run (Thompson et al. 2019a)….
>
> High levels of interbreeding currently reported in some areas indicate that early and late individuals substantially overlap in space and time. In some locations that might have occurred historically, but in others this pattern suggests that early individuals have lost access to their historic habitats, or late individuals are now able to access them. In either case, it is likely that the late-run phenotype would experience a competitive advantage because they would not have to face the same risk-benefit tradeoffs as early-migrating individuals….

> US Fish and Wildlife surveys noted a reduction in spatiotemporal segregation between spring- and fall-run spawning in the Chehalis basin after a dam was built (Hiss et al. 1985), and a substantial proportion of heterozygotes observed in the Chehalis were sampled near this dam (Thompson et al. 2019b)."

Thus, the best available science indicates that reproductive isolation of spring-run Chinook from fall-run Chinook is necessary for both the accrual and maintenance of spring run-timing. In other words, without reproductive isolation from fall-run Chinook, the best available science suggests that spring-run Chinook would not have evolved in the first place and cannot be expected to persist. Therefore, in a healthy watershed with robust spring-run Chinook, the level of reproductive isolation between spring- and fall-run Chinook must be sufficient for spring run-timing to accrue and be maintained, or the watershed would not be expected to contain significant numbers of spring-run Chinook. That is also why habitat alterations that decrease reproductive isolation are existential threats to spring-run Chinook.

The second criterion requires that spring-run Chinook constitute an important component in the evolutionary legacy of the species. In this context, "evolutionary legacy" includes both the product of past evolutionary events as well as the raw material for future evolution. The evolutionary importance of spring run-timing is discussed throughout Waples et al. (2022):

> "The evolutionary history of the GREB1L/ROCK1 region is complex and has not been well characterized throughout each species' entire range. But it is clear that the early and late haplotypes evolved long ago in each species' evolutionary history (Prince et al. 2017; Thompson et al. 2020). Based on available data, it is also clear that allelic variants for early migration have not arisen independently via new mutations from the genomic background of late migration individuals in each watershed….
>
> Spring Chinook salmon and summer steelhead occupy a specialized ecological niche—upstream areas accessible primarily during spring flow events… this indicates that strong conservation measures focused on early-run populations are needed, because genetic change and biodiversity loss can compromise both the current viability and the future evolutionary potential of the species."

The best available science indicates that spring-run Washington Coast Chinook meet both requirements of the ESU policy, and therefore, may be considered as a separate ESU from their fall-run counterparts.

Previously, a NMFS scientific review panel concluded that spring-run Chinook salmon from the Oregon Coast or SONCC do not meet the requirements of the ESU policy (Ford et al. 2021). This scientific review panel's report (Ford et al. 2021) implied there is a scientific consensus that spring-run Chinook should not be considered a separate ESU from co-occurring fall-run Chinook based on new genomic data. More specifically, Ford et al. (2021) states that conclusions about conservation units "should generally be defined on the basis of variation throughout the genome, rather than on the basis of small genomic regions associated with specific traits." Waples et al. (2022) concluded that "using patterns of genetic variation throughout the genome remains important for identifying CUs, rather than identifying units based solely on small genomic regions associated with specific traits". However, the interpretation of Ford et al. (2021) is not accurate. Waples et al. (2022) does not imply that the small genomic region associated with run timing should not be used in defining conservation units, it rather indicates that this genomic region should not be the <u>only</u> basis for defining conservation units.

The previous Oregon Coast and SONCC petitions, as well as this Washington Coast petition, do not suggest defining ESUs based solely on a small genomic region (i.e., the GREB1L/ROCK1 region). If ESUs were based solely on the GREB1L/ROCK1 region, all spring-run Chinook from throughout their geographic range would be grouped into a single ESU, and the same for fall-run Chinook. Instead, these petitions suggest splitting current ESUs, whose geographic boundaries are defined according to patterns of genetic variation throughout the genome, based on new genomic data. Therefore, the resulting ESUs would be based on both patterns of genetic variation throughout the genome as well as data from the GREB1L/ROCK1L region. For example, for a Washington Coast spring-run Chinook ESU, the "Washington Coast" component would be based on patterns of variation throughout the genome whereas the "spring-run" component would be based on the GREB1L/ROCK1L region. Thus, a separate ESU for Washington Coast Spring Chinook is completely consistent with the Waples et al. (2022) conclusion that "using patterns of genetic variation throughout the genome remains important for identifying CUs, rather than identifying units based solely on small genomic regions associated with specific traits."

Furthermore, the Ford et al. (2021) conclusion that spring-run Chinook salmon from the Oregon Coast or SONCC do not meet the requirements of the ESU policy is based heavily on fact that spring- and fall-run Chinook are only differentiated by a single genomic region (i.e., the GREB1L/ROCK1L region). For example, the "Conclusion" section from Ford et al. (2021) states that "the available data indicate that spring-run Chinook salmon in the OC and SONCC ESUs ... share a recent evolutionary history throughout the vast majority of their genome with fall-run Chinook salmon in the same rivers. We therefore conclude that spring-run Chinook salmon in the OC or SONCC ESUs do not meet the criteria for being separate ESUs under the NMFS ESU policy."

The number of genomic regions (a.k.a., loci) that influence a trait is referred to as "genetic architecture". A trait controlled by a single locus has a "simply-inherited" genetic architecture, whereas a trait controlled by many loci has a "polygenic" genetic architecture. Thus, even though the ESU policy does not mention genetic architecture (either directly or indirectly) for evaluating ESUs, Ford et al. (2021) rely heavily on the fact that run-timing has a simply-inherited genetic architecture to concluding that spring-run Chinook salmon from the Oregon Coast or SONCC do not meet the ESU criteria.

This interpretation of Ford et al. (2021) is not consistent with the best available science because, in reality, the fact that run-timing variation has a simply-inherited genetic architecture is one of the key reasons why spring run-timing is so significant from an evolutionary perspective. For example, Waples et al. (2022) state:

> "Discovery that specific alleles in one genomic region are associated with the early-run trait implies that the trait is at greater risk than if it were highly polygenic, because loss of the "early" allele(s) equates to loss of the phenotype. If early allele(s) were recessive, a genetic reservoir might persist in late-run populations, but that does not appear to be the case. Available evidence indicates that early allele(s) are codominant or partially dominant, and surveys in multiple Chinook salmon populations indicate that early alleles disappear or become extremely rare after extirpation of the early phenotype. This indicates that, although hatchery propagation might be an important conservation strategy and source of early-run alleles in the short term, the only reliable way to conserve early-run genes in nature is by maintaining habitat that supports early-run phenotypes."

and

> “The evolutionary history of the GREB1L/ROCK1 region is complex and has not been well characterized throughout each species’ entire range. But it is clear that the early and late haplotypes evolved long ago in each species’ evolutionary history (Prince et al. 2017; Thompson et al. 2020). Based on available data, it is also clear that allelic variants for early migration have not arisen independently via new mutations from the genomic background of late migration individuals in each watershed.”

Thus, the fact that run-timing variation is simply-inherited as opposed to polygenic is the primary reason why, if lost, spring-run Chinook cannot be expected to rapidly re-evolve from their fall-run counterparts. And this lack of replacement is supposed to be an important consideration in evaluating the ESU criteria. For example, Waples (1991) states:

> “If all individuals in the population in question were permanently removed, would the area naturally be repopulated by individuals of the same biological species, and if so, within what time frame? Presumably, an area that would be naturally repopulated at or near the previous abundance level in a short time would be unlikely to harbor an ESU.”

### D. Alternate Basis for Listing Washington Coast Chinook ESU (Spring and Fall Run)

Spring-run Washington Coast Chinook represent a critical component of life-history diversity within the currently defined Washington Coast Chinook ESU that includes both spring- and fall-run fish. Waples et al. (2022) extensively discusses the importance of and threats to spring-run Chinook:

> “Even if [ESU] configurations remain unchanged, it is important to consider ramifications of the new genomics data for assessments of population viability. Important considerations include the following: Spring Chinook salmon and summer steelhead occupy a specialized ecological niche—upstream areas accessible primarily during spring flow events—and status review and recovery planning teams have consistently concluded that viable populations of both early- and late-migrating forms are necessary for the larger ESUs as a whole to be considered viable (Busby et al. 1996; Myers et al. 1998; McElhany et al. 2006; Shared Strategy Development Committee 2007; Dornbush 2013; Hard et al. 2015; Pearse et al. 2019). These specialized habitat requirements make early-run populations particularly vulnerable to decline or extirpation due to habitat degradation, blockage of migratory routes, climate change, and interactions with hatchery and harvest management (Nehlsen et al. 1991; Gustafson et al. 2007; Tillotson et al. 2021). Discovery that specific alleles in one genomic region are associated with the early-run trait implies that the trait is at greater risk than if it were highly polygenic, because loss of the “early” allele(s) equates to loss of the phenotype. If early allele(s) were recessive, a genetic reservoir might persist in late-run populations, but that does not appear to be the case. Available evidence indicates that early allele(s) are codominant or partially dominant, and surveys in multiple Chinook salmon populations indicate that early alleles disappear or become extremely rare after extirpation of the early phenotype. This indicates that, although hatchery propagation might be an important conservation strategy and source of early-run alleles in the short term, the only reliable way to conserve early- run genes in nature is by maintaining habitat that supports early-run phenotypes.”

Other work led by NMFS scientists has detailed the rationale for population viability to depend on the maintenance of run timing diversity in their description of Viable Salmon Populations (McElhany et al. 2006). Run timing diversity contributes to population viability by allowing salmonids to use a greater variety of spawning habitats than would be possible without this diversity. Run timing diversity protects a species against short-term spatial and temporal changes in the environment. Fish with different run timings have different likelihoods of persisting, depending on local environmental conditions. Therefore, the more diverse a population is, the more likely it is that some individuals would survive and reproduce in the face of environmental variation and anthropogenic threats. Run timing groups such as spring-run and fall-run harbor unique genetic diversity that provides the raw material for surviving long-term environmental changes. Salmonids regularly face cyclic or directional changes in their environments due to natural and human causes, and genetic diversity allows them to adapt to these changes.

Salmon researchers from Wild Salmon Center, NOAA Fisheries, Fisheries and Oceans Canada, Washington Department of Fish and Wildlife, and Simon Fraser University analyzed abundance trends, including regional trends in spawner escapement and total run size, for more than 80 Chinook populations extending from California's Sacramento River north to the Fraser River in Canada (Atlas et al. 2023). The research of Atlas et al. (2023) indicates that Chinook life history diversity has been key to the ability of some Chinook runs to thrive in the face of climate change.

As laid out in the basin-by-basin status reviews and the threats sections below, spring-run Washington Coast Chinook are facing existential threats, and therefore, if the ESU configuration does not change, the current Washington Coast ESU that includes both spring- and fall-run Chinook cannot be considered viable and must be listed under the ESA in order to preserve the unique, evolutionarily significant spring-run life history.

### E. Pros and Cons of Reconfiguring ESU Structure

The previous sections present scientific justifications for two approaches to protect Washington Coast spring-run Chinook under the ESA. The first approach would reconfigure the ESU structure by defining and listing a new Washington Coast spring-run Chinook ESU, whereas the second approach would list the presently defined ESU, which includes both spring- and fall-run Chinook, based primarily on spring-run declines. Waples et al. (2022) discusses the pros and cons of reconfiguring ESUs based on the recent genomic data with the following:

> "What are some of the potential implications for CU designations? Answering this question requires consideration of inherent tradeoffs between lumping and splitting in defining CUs, as well as the objectives one is trying to accomplish. Different management goals can result in different CU configurations, so there is unlikely to be a single "correct" way to identify CUs. Our literature review indicated that large-effect loci are not uncommon, in salmonids as well as other species, so identifying CUs based on these small genomic regions could potentially lead to an unmanageable plethora of small CUs, or situations in which different large-effect loci suggest conflicting CU configurations. Conversely, including multiple life-history types within a single CU could also be potentially problematic by making it more difficult to implement separate conservation and management regimes. Furthermore, because not all large-effect loci warrant equal consideration from a conservation perspective, due to their highly variable characteristics (e.g., effect size, trait importance, dominance pattern), potential problems associated with fine-scale splitting of CUs could be alleviated by developing stringent criteria for evaluating if/when large-effect loci might be useful in CU identification (Kardos and Shafer 2018)."

The primary con of splitting is a slippery slope argument, because large-effect loci are not uncommon. In other words, if presently defined ESUs are split by run-type (i.e. spring- vs fall-run), ESUs might end up needing to be split in many other situations too, which could lead to an unmanageable number of ESUs. However, Waples et al. (2022) provides an approach to alleviate this problem. More specifically, Waples et al. (2022) acknowledges that not all large-effect loci warrant equal consideration from a conservation perspective and suggests that stringent criteria could be developed to prevent splitting from getting out of hand. Related to this, although Waples et al. (2022) provides a table that includes several examples of large-effect loci, but unlike spring run-timing, it does not appear that any of these other examples have the same combination of attributes to warrant a high conservation priority. With run-timing in Chinook, a specific, critically important phenotypic variant is experiencing severe declines throughout its range when the other phenotypic variant remains relatively healthy, and loss of the specific phenotypes equates to loss of the anciently-evolved allele due to an extreme combination of effect size and dominance. Thus, developing stringent criteria to alleviate the slippery slope problem appears highly feasible.

On the other hand, the primary con of not splitting is difficulty implementing separate conservation and management regimes for spring- and fall-run Chinook when they are part of the same ESU. Unlike the slippery slope problem, Waples et al. (2022) does not suggest a way to alleviate this problem, which unfortunately, could be very challenging for some critical conservation actions needed to prevent the extinction of spring-run Chinook. More specifically, one of the only conservation actions that would provide immediate relief for spring-run Chinook is reversing artificially high rates of interbreeding and competition from fall-run Chinook. Feasible courses of action are available for this such as re-establishing historical barriers and/or restoring natural flow regimes to prevent fall-run from accessing spatiotemporal spawning habitat that was historically exclusively (or nearly exclusively) used by spring-run Chinook. In fact, some of these actions are already being pursued in the Chehalis Basin (within the Washington Coast ESU). However, if the presently defined ESU that includes both spring- and fall-run were listed, these activities could be severely hindered because they benefit spring-run at the expense of fall-run. If both spring- and fall-run were listed, these actions would likely be considered take of listed fall-run, even though fall-run are relatively abundant and the actions are needed to save spring-run.

### F. Traditional Ecological Knowledge

NMFS's status review of Washington Coast spring-run Chinook should incorporate Traditional Ecological Knowledge (TEK), that is Indigenous traditional knowledge of local resources, acquired by local peoples over hundreds or thousands of years through direct contact with the environment. There is extensive TEK documented about the differences and distinctions between spring-run and fall-run Chinook salmon.

## II. Biology and Ecology of Washington Coast Chinook

### A. Range and Distribution

The Washington Coast Chinook salmon ESU encompasses coastal basins north of the mouth of the Columbia River and southwest of the Lyre River in Washington. Washington Coast spring-run Chinook salmon are distributed broadly along the Washington Coast ESU in five major watersheds, the Chehalis, Quinault, Queets/Clearwater, Hoh, and Quillayute River basins. See Figure 1.

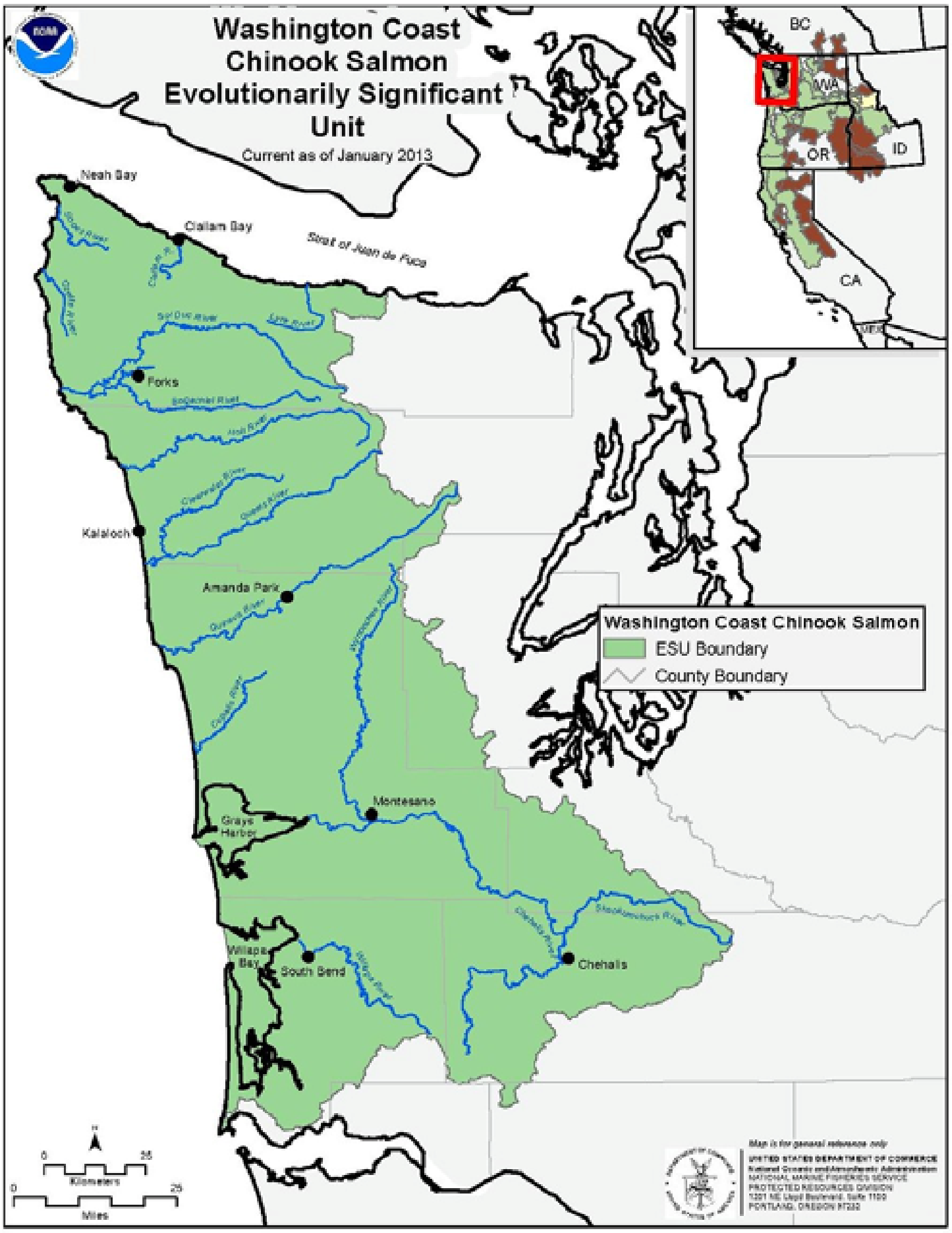


Figure 1. Washington Coast Chinook Salmon ESU Range Map from NMFS

## B. Life Cycle and General Biology

Chinook salmon are anadromous, though some small males may occasionally mature in freshwater as a resident (Quinn 2018). Chinook salmon will spend from several weeks up to six consecutive years in the ocean before returning to freshwater where females excavate a nest (redd) in the gravel and mate with males as they deposit their eggs into the substrate (Quinn 2018). Chinook salmon grow through six basic life history stages: eggs, alevins, fry, parr, smolts, and adults. Eggs will remain in the gravel for a period of weeks to months depending on water temperature and intra-gravel flow (Quinn 2018). Alevins are larvae that hatch from the eggs and still contain their yolk sac, and they often remain buried in the gravel until the yolk-sac has been absorbed and they need to begin exogeneous feeding (Quinn 2018). After the yolk is absorbed, the fish becomes a fry, at which point the fry begin to emerge from the gravel for short periods to feed. After the first month or two of life the fish become parr. Parr are larger and better swimmers and are denoted by their oval parr marks along their lateral line. After residing in freshwater for weeks up to a year, the parr will begin to undergo a physiological transformation called smoltification that allows them to balance the higher salt-content in the ocean (Quinn 2018). During this process, the fish will begin moving passively downstream before they enter the ocean, after which the smolts may utilize near-shore estuary habitat before beginning their marine migration (Quinn 2018). Both spring- and fall-run juvenile Chinook salmon born in rivers along the Washington Coast have a northerly migration and generally remain within coastal waters along the continental shelf (Wood 1984; Myers et al. 1998; Riddell et al. 2018).

The long period of time spent in the ocean allows Chinook to attain the largest size of any Pacific salmon. Their uniquely large body size conveys several evolutionary benefits to Chinook salmon, such as greater energy reserves for migration, greater strength and capacity for excavating redds in larger substrate than other salmonids, and increased production of potential offspring (Quinn 2018). Fecundity of female Chinook salmon can range from 2,000 up to 17,000 eggs, with an average of 5,400 eggs that are each approximately 9 mm in diameter, which is the greatest average fecundity and egg size among Pacific salmon species (Quinn 2018). Despite the value of attaining a larger size, research indicates that body size of Chinook salmon has been declining across the North Pacific due to fishing and climate change, raising concerns about their long-term fitness and viability (Ricker 1981; Ohlberger et al. 2019).

## C. Life History Diversity

Chinook salmon display a broad array of life history strategies that include: variation in age at seaward migration; length of freshwater, estuarine, and oceanic residence; ocean distribution and ocean migratory patterns; and age and season of spawning migration. Differences in Chinook salmon life histories are best explained by the timing of their spawning migration (e.g., spring-run, fall-run) and by the length of their juvenile residence in freshwater (i.e., stream-type or ocean-type).

Ocean-type Chinook salmon migrate to the ocean typically within their first three to four months of life after emergence as fry from spawning gravels (Healey 1991; Quinn 2018). Washington coastal Chinook, both spring- and fall-run types, predominantly have an ocean-type life history. In contrast, stream-type Chinook typically spend a year rearing in freshwater before migrating seaward; while this juvenile life history type may be expressed by individuals in some coastal spring-run Chinook populations, this life history type is more common to interior rivers east of the Cascade Mountains and in rivers north of 56° north latitude (Quinn 2018; Riddell et al. 2018).

Both spring- and fall-run Chinook salmon are currently found on the Olympic Peninsula. Fall-run Chinook salmon are currently the most abundant, while spring-run Chinook are the least abundant. Fall-run Chinook enter freshwater in late summer through fall in a relatively mature state and spawn shortly thereafter from October through January, with most of their offspring migrating to the ocean after spending only a few months in freshwater (i.e., an ocean-type juvenile life history). Spring-run Chinook also most commonly display an ocean-type juvenile life history, but in contrast with fall-run Chinook, they enter freshwater streams while still relatively sexually immature during spring (March through June) and mature in freshwater before spawning in late summer through early fall. Spring-run adults migrate high into watersheds, arrive near their eventual spawning grounds, and then hold over the summer in a fasted state in deep freshwater pools (usually greater than 2 meters depth) to allow their gonads to develop before spawning in late summer to early fall (NRC 2004). Because spring-run Chinook enter rivers several months before spawning, they are sometimes referred to as “premature” migrators, and “early” migrators; fall-run Chinook are sometimes referred to as “mature” migrators, and “late” migrators” (Quinn et al. 2016; Waples et al. 2022).

Spring-run adults require deep, cold holding pools in streams proximate to spawning areas, where they hold and mature for 3-6 months prior to spawning; this holding period occurs during the summer, when flows are naturally the lowest and water temperatures the warmest (Kostow 1995). In contrast, fall Chinook tend to spawn in the lower sections of watersheds and in lower-elevation rain-fed tributaries.

In Washington coastal rivers, Chinook referred to as summer-run are those that enter the rivers from late June to the end of August. Summer-run Chinook that enter the Washington north coastal rivers in summer months generally display an intermediate distribution in spawn location and run timing between the earlier entering spring Chinook and the later entering fall Chinook (Lestelle 2019). The best available genetic evidence indicates that summer-run Chinook in coastal Washington rivers are the product of interbreeding between spring-run and fall-run Chinook salmon (see Kinziger et al. 2008)

Since the early 1980s, biologists and fishery managers on the Oregon and Washington coasts have often grouped spring- and summer-run Chinook salmon together, calling them simply spring-run or spring/summer-run fish, referring to all adult Chinook that start entering the rivers as early as March and continuing through the end of August (Wood 1984; Nicholas and Hankin 1988; Lestelle et al. 2019). This convention was adopted before recent advances were made in the understanding of the genetic basis for Chinook run timing, which is determined by specific alleles in one small genomic region (Prince et al. 2017; Thompson et al. 2019; Waples et al. 2022). This discovery has enabled the detection of genetic differences between run types that are relevant to both the naming conventions for Chinook salmon run types and their status. Unless otherwise noted, the term “spring-run Chinook salmon” is used to refer to fish that have homozygous (having identical alleles at a particular gene locus) “early” alleles at previously identified run timing loci (i.e., “homozygous early”); “fall-run Chinook salmon” refers to fish that have homozygous “late” alleles at run timing loci (i.e., “homozygous late”); and “summer-run Chinook salmon” refers to fish that are heterozygous, having one early and one late migration allele at run timing loci (i.e., “heterozygotes”).

Spring Chinook require about 258 square feet of well oxygenated gravel per spawning pair (Burner 1951). Females defend their redd during and after spawning. Early in the spawning period they can stay on the redds for about two weeks, while their residence late in the season is only 4-5 days. Spawning adults can be chased off redds easily by minor disturbances, which if they occur frequently enough can result in death of the adult prior to successful spawning. Eggs are laid in depressions excavated on the bottom of streams in shallow river reaches. Chinook eggs are the largest of all Pacific salmon species with a small surface-to-volume ratio, making them more sensitive to reduced oxygen levels than other Pacific salmon (Hendry et al. 2001).

Several months after egg deposition the small fry emerge from the gravel. Adequate water flows through the spawning gravels are essential for egg and alevin survival. Stream conditions, particularly those affecting subgravel flows, can have a dramatic effect on the survival of eggs to hatching and emergence. Any increases in siltation in spawning beds can cause high mortality (Healey 1991). At the time of emergence, fry generally swim or are displaced downstream, although some fry are able to maintain their residence at the spawning site.

Chinook spend most of their ocean life in coastal waters, with ocean-type fish rarely moving far offshore while in the ocean and tending to limit their dispersal to not more than about 620 miles from the mouth of their natal stream (NMFS 1998a). Chinook salmon spawned in coastal Washington streams migrate north, being caught in fisheries along British Columbia and southeast Alaska (Wood 1984; NMFS 1998a).

### 1. Evolutionary Significance of Spring Chinook Life History

Spring-run Chinook populations represent a major contribution to life history variation in Chinook salmon at the species level, but also at the level of river-specific stocks (Nicholas and Hankin 1988). Life history variation within species, and both among and within populations, is now widely recognized as a critical factor in determining salmon viability, productivity, and resilience in the face of environmental fluctuations and anthropogenic threats. Life history diversity in salmon populations affords a critical buffer against both large-scale and local environmental variation (Schindler et al. 2010; Brennan et al. 2019). The loss of life history diversity in Chinook salmon, whether by decline or extirpation of local populations, or by demographic dominance of hatchery-reared fish, leads to increasing synchronicity of population fluctuations, hence reduced resilience and productivity, and increasing risk of local extinctions (Moore et al. 2010; Carlson and Satterthwaite 2011; Satterthwaite and Carlson 2015).

Among the known and strongly suspected specific ecological and evolutionary benefits of inclusion of the spring-run migration genotype in Chinook salmon populations are:

1) Access is afforded to headwater habitats that often lie above natural falls or cascades, or reaches of intermittent flow that are commonly not passable by fall-run Chinook salmon.

2) The greater range of spatial and temporal habitat occupation afforded by spring-run life histories confers resilience to Chinook salmon in the face of extreme events and environmental catastrophe, through spreading of risk of mortality. Conversely, such diversity increases the likelihood of some population segments finding favorable habitat in seasons and years when others are suffering.

3) Early migration allows spring-run Chinook to ascend to spawning habitat before the onset of problematic or lethal water temperature, streamflow, and migration barriers that adversely affect fall Chinook salmon in years of fall season drought.

4) Earlier spawning and longer periods of egg incubation are possible, which is likely an important adaptation to colder, groundwater-dominated and other headwater habitats.

5) In part because of their spatial concentration of spawning nearer headwater areas, offspring of spring-run Chinook may have more options to express variety in the timing and location of freshwater rearing, downstream migration, and smolting; for example, they often include both stream-type and ocean-type life histories, and may express a greater diversity of seasonal juvenile movements and ocean entrance.

6) Maintenance of both spring- and fall-run Chinook increases the spatial dispersion of adult Chinook salmon within watersheds, ensuring that the marine nutrient subsidy incorporated in their body mass is well-distributed throughout the stream network, including into near-headwater areas. This can benefit the salmon themselves, as well as other species.

The presence of spring Chinook in headwater zones of basins could protect them in the face of catastrophic mortality events such as natural catastrophes or toxicant spills that could widely affect downstream-distributed fall Chinook populations (Good et al. 2008). By ascending migration barriers, spring Chinook escape the presence of several other fish species. Hence, they may be less vulnerable to potential pathogen outbreaks that spread horizontally among species, and less affected by interspecific competition for limited food and habitat. And in the face of future climate change, downstream habitats principally inhabited by fall Chinook in coastal rivers could become so warm and flow-depleted (Luce and Holden 2009; Isaak et al. 2012; Dalton et al. 2013) as to become marginally inhabitable by early fall spawning and rearing juvenile Chinook salmon, whereas habitat conditions for headwater-adapted salmonids might remain within tolerable limits (Crozier and Zabel 2006; Isaak and Rieman 2012; Muñoz et al. 2015).

Early- and late-returning Chinook salmon may also face different conditions in the marine environment, so may be affected much differently by effects of changes in marine currents and predation. Moore et al. (2014) identified early and late adult return timing as one of several life history variations that contributed to dampening fluctuations in population abundances and biomass via portfolio effects in steelhead populations in British Columbia. This observation constitutes a specific example of the “portfolio effect” of within-basin diversity that confers stability, spreads risk of stresses and threats, and sustains the productive capacity of salmon populations (Brennan et al. 2019).

The role of adult salmon carcasses in spawning areas in transferring important marine nutrients to often nutrient-limited freshwater and inland riparian ecosystems is well-recognized (Cederholm et al. 2000; Gresh et al. 2000; Zabel and Williams 2002; Peery et al. 2003; Scheuerell et al. 2005; Schindler et al. 2010). The increased spatial and temporal dispersion of Chinook salmon furthered by the presence of spring-run ecotypes, particularly in wild populations, supports this natural ecosystem enrichment function. An integral part of this nutrient transfer is the role that spawning and post-spawning spring- and summer-run Chinook play in providing a reliable natural food resource for other animals: guilds of predators and scavengers, including many birds, mammals, fishes, and invertebrates (Cederholm et al. 2000; Minikawa et al. 2002; Peery et al. 2003; Schindler et al. 2010; Field and Reynolds 2013). Some northeast Pacific orcas, particularly the Southern Resident orcas, are strongly selective foragers on Chinook salmon (Ford and Ellis 2006; Giles et al. 2018), such that the contribution of spring-run Chinook salmon to overall stability and abundance of the species at sea is believed to play a significant role in orca health and survival.

## D. Habitat Requitements

Chinook salmon require specific habitat conditions throughout the large array of habitats they depend upon to complete their life cycle. There is a significant body of scientific study regarding freshwater habitat use and requirements for Chinook salmon, although estuarine and ocean conditions are also significant to the survival and viability of the species. Spring-run Chinook salmon rely on several freshwater habitat components including migratory corridors, spawning habitat, and rearing habitat. Human activities can significantly degrade freshwater and estuarine habitat suitability.

### 1. Migration and Spawning Habitat

Adult Chinook rely on stored energy to complete their journey upstream. This places them in a stressed condition, which makes them highly susceptible to additional environmental stressors (Bowerman et al. 2021). Although the distances that adult spring-run Washington Coast Chinook salmon migrate are relatively short compared to other salmon migrations in larger river systems, migration through Washington's coast range and the Olympic Mountains still requires considerable effort.

Chinook salmon require access to spawning habitat in mainstem rivers and tributaries, cold water, cool pools in which to hold, clean spawning gravel, and particular dissolved oxygen levels, water velocities, and turbidity levels to successfully migrate and spawn (Quinn 2018). Access to spawning habitat is threatened by migration barriers, dams, and water diversions. Variability in water flows can prevent Chinook salmon access to certain streams for spawning. During migration and spawning, low water temperatures are crucial to the success of Chinook salmon.

Adult spring-run Chinook migrate early before their gonads are fully developed and then hold in deep cool pools before spawning (Quinn et al. 2016). The presence of deep cold-water pools is essential to the survival of spring-run fish in particular. Optimal adult holding habitat for spring-run Chinook is characterized by pools or runs greater than one meter deep (>2 meters deep for long-term holding) with cool summer temperatures (<20°C), all day riparian shade, little human disturbance, and underwater cover such as bedrock ledges, boulders, or large woody debris (West 1991). Dams, water withdrawals, logging, mining, and grazing can all contribute to decreased summer and fall stream flows, reduced channel stability, loss of woody structure, infilling of pools by sediment, and warming water temperatures that compromise the distribution and quality of deep pools that are essential holding habitat for spring Chinook.

During the adult holding period, spring-run Chinook are vulnerable to low flow and high water temperature, which can prevent them from reaching their spawning destinations and significantly increase mortality during migration (Moyle et al. 1995; Trihey and Associates 1996). Spring Chinook are more sensitive to high temperatures than fall Chinook (Allen and Hassler 1986).

According to McCullough (1999), adult Chinook are more sensitive to higher temperatures than juveniles, as higher temperatures can increase the adults' metabolic rate and deplete their energy reserves, weaken their immune system, increase exposure to diseases, and slow or prevent migration. Water temperatures at or above 15.6$^{o}$C can increase the risk of onset and severity of diseases (Allen and Hassler 1986). Healthy and intact riparian vegetation is critical, as it provides much needed root strength to stabilize stream margins and floodplains, and shade to keep water cool (Moyle 2002) and help create "thermal refugia" in which migrating Chinook salmon can escape high temperatures (Berman and Quinn 1991; Torgerson et al. 1999; Gonia et al. 2006). The presence of suitable cold water habitat is threatened by dams, water withdrawals, and channel alterations, as well as logging and grazing which decrease riparian vegetation.

The relatively small size of the rivers used for spawning by Washington coast spring-run Chinook limits the amount of spawning habitat available. Spawning occurs primarily in low gradient habitats with large cobbles loosely embedded in gravel and with sufficient flows for subsurface infiltration to provide oxygen for developing embryos (Healy 1991; Moyle et al. 2008). Optimal spawning temperatures for Chinook salmon are less than 13°C (McCullough 1999). Migrating adults also need dissolved oxygen levels above 5 mg/l, deep water (deeper than 24 cm), breaks from high water velocity, and water turbidity below 4,000 ppm (NRC 2004). Spawning gravel also must be free of excessive sediment such that water flow can bring dissolved oxygen to the eggs and newly hatched fish. With too much sediment, incubating eggs are smothered and reproductive success rate declines significantly. Logging, mining, and grazing can increase inputs of fine sediment in Chinook spawning habitat and significantly reduce fry emergence rates and embryo survival.

Spring Chinook salmon juvenile growth, survival, and migration behavior during freshwater rearing can be influenced by streamflow and water temperature (Sauter et al. 2001; Richter and Kolmes 2005; Sykes et al. 2009; Walters et al. 2013). Reduction of summer stream flows also adversely affects volume and temperature of summer holding habitat for migrating adult salmon (Berman and Quinn 1991; Quinn and Adams 1996; Torgerson et al. 1999; Crozier et al. 2008).

Mature forests in coastal Washington are known to play an important role in regulating suitability of stream flows and stream temperature for spring Chinook salmon. Crozier and Zabel (2006) examined a suite of environmental factors relating to stream flow and water temperature in streams in the Salmon River basin of Idaho and evaluated their relation to survival among populations of spring/summer Chinook salmon. They found that some populations were more strongly correlated with fall streamflow (during the period when juveniles move to seek freshwater overwintering habitats), while others were more strongly (inversely) correlated with summer water temperature. Crozier and Zabel (2006) predict that climate change in the form of atmospheric warming would differentially affect these two population groups, because they reside in habitats with differential sensitivity to warming climate. Some streams are relatively resistant to warming from atmospheric forcing by nature of their groundwater hydrology (Arismendi et al. 2015; Fullerton et al. 2015; Isaak et al. 2018), but in those cases, declining summer flows may limit juvenile Chinook growth and survival by other means, including: reducing food supply; crowding that increases intra-and inter-specific competition for food, space, and shelter; trapping of juveniles in stream reaches or pools isolated by increasing intermittent low flows; and increased vulnerability to predation.

### 2. Juvenile Rearing Habitat

During rearing and juvenile out-migration, Chinook require specific temperatures and water quality characteristics, as well as a diversity of habitat components. After hatching, juvenile Chinook must find suitable rearing habitat to grow and develop (i.e., smoltification) before making their migration to the estuary and onto the ocean. Ideal fry rearing temperature is estimated at 13$^{o}$C; temperatures above 17$^{o}$C are linked with increased stress, predation, and disease. High water temperatures can prevent smoltification, an essential process that prepares fish to leave freshwater habitat (McCullough 1999).

During juvenile rearing and downstream dispersal, spring-run Chinook are vulnerable to low flow and high temperature conditions, which can prevent them from reaching their destinations and significantly increase mortality during migration (Moyle et al. 1995; Trihey and Associates 1996). Stream temperature during out-migration is critical, as prolonged exposure to temperatures of 22-24$^{o}$C has resulted in high mortality for migrating smolts, and juveniles who transform into smolts above 18$^{o}$C may have low survival odds at sea (Baker et al. 1995; Myrick and Cech 2001). Hence, where and when necessary, juvenile Chinook salmon also seek out and exploit localized cool water refugia that offer relief from warm ambient water temperatures in summer (Sauter et al. 2001; Belchik 2003; Ebersole et al. 2003; Sutton et al. 2007).

Riparian vegetation provides relief for juvenile Chinook from high temperatures, as well as shelter from predators (Moyle 2002). Logging, mining, and grazing can all reduce streamside vegetation. Habitat diversity is important for juvenile Chinook survival, as juveniles face predation by fish and invertebrates, as well as competition for rearing habitat from other salmonids, including hatchery Chinook and steelhead trout (Healey 1991; Kelsey et al. 2002). Chinook require the correct grades of gravel, the right depths and prevalence of deep pools, the existence of large woody debris, and the right incidence of riffles (Montgomery et al. 1999). This allows for a variety of habitats which are required by Chinook at different life stages.

Chinook fry may compete for shallow water rearing habitat with hatchery fish and steelhead. Increased river flows mitigate this competition and help Chinook survival by increasing habitat on the river's edge, where fry (under 50 mm) feed and hide from predators (NRC 2004).

As juvenile Chinook migrate down river, they prefer boulder and rubble substrate, low turbidity and water velocity slower than 30 $cms^{-1}$ (Healey 1991). These conditions allow juveniles to use the faster-moving water in the center of the river for drift feeding, while resting in the slower areas (Trihey and Associates 1996). Smaller fish tend to stay in the slower-moving water near the banks of the river. Logging and grazing can increase turbidity, and climate trends increase the frequency and size of flood peaks scouring redds and/or prematurely displacing fry and young parr.

Juvenile Chinook require high levels of dissolved oxygen (DO). Low DO levels decrease alevin and fry survival; decrease successful Chinook egg incubation rates; decrease the growth rate for surviving alevins, embryos, and fry; force alevins and juveniles to move to areas with higher DO; and negatively impact the swimming ability of juvenile Chinook (NCWQCB 2010). If DO levels average lower than 3-3.3 mg/L, 50% mortality of juvenile salmonids is likely, while in water above 20°C, daily minimum DO levels of 2.6 mg/L are required to avoid 50% mortality (NCWQCB 2010). Logging, agriculture, diversions, and dams can contribute to suboptimal DO levels (NCWQCB 2010).

Chinook salmon also require pH levels that are not too high. Even high pH levels which are not directly lethal to salmonids can cause harm, including decreased activity levels, increased stress responses, a decrease or cessation of feeding, and a loss of equilibrium (NCWQCB 2010). Few studies directly examine the effects of high pH values on Chinook salmon, however rainbow trout are stressed by pH values above 9 and generally die if the pH value rises above 9.4 (NCWQCB 2010). Nutrient loading of stream systems from agricultural runoff can lead to higher and diurnally fluctuating pH in river systems (NCWQCB 2010).

Once juvenile Chinook reach the estuary, spring-run smolts prefer nearshore areas near the mouth of the river (Healey 1991). Juveniles change location with the tide as the salinity of the water changes. Larger Chinook smolts seek out deeper pools to avoid light.

### 3. Ocean Habitat

Once Chinook enter the ocean, most reside at depths of 40-80 meters (Healey 1991). Some research suggests that spring-run Washington Coast Chinook migrate north nearshore, following fall Chinook migration patterns. In contrast, Healey (1983) hypothesized that spring Chinook are distributed mostly beyond the continental shelf in the open ocean during ocean residence, while fall

Chinook have a more coastal distribution along the continental shelf. However, Healey's hypothesis was based primarily on observations from interior Chinook salmon stocks (e.g., from the Columbia and Fraser rivers) and assumed that spring-run Chinook have obligate stream-type juvenile life histories, migrating to the ocean as yearling smolts. Sharma (2009) found that the ocean distribution of coastal spring-run Chinook populations have an ocean-type life history, overlapped with fall Chinook and had a more coastal ocean distributions. The large majority of spring-run and fall-run fish within Oregon and Washington coastal Chinook populations have an ocean-type life history (Nicholas and Hankin 1988; Lichatowich and Mobrand 1995). Coded wire tag data for Hoh River spring Chinook demonstrate a coastal ocean distribution (Wood 1984).

In the marine environment, Chinook salmon require nutrient-rich, cold waters associated with high productivity and higher rates of salmonid survival. Warm ocean regimes are characterized by lower ocean productivity which can affect salmon by limiting the availability of nutrients regulating the food supply and increasing the competition for food. Climate and atmospheric circulation conditions can affect these conditions (NMFS 1998c). To survive in the marine environment, Chinook salmon also require favorable predator distribution and abundance. This can be affected by a variety of factors including large scale weather patterns such as El Niño. NMFS (1998c) cites several studies which indicate associations between salmon survival during the first few months at sea and factors such as sea surface temperature and salinity.

The role of changing ocean conditions in influencing the survival of spring-run Washington Coast Chinook and other salmon is considerable. However, predictive understanding of marine survival of wild spring-run Washington Coast Chinook salmon is elusive, in part due to fluctuating ocean conditions, but also because few data are collected on marine survival of wild populations.

Sharma and Liermann (2010) concluded that change in sea surface temperature anomalies reflected in the El Niño phenomenon in recent decades have produced ocean conditions increasingly hostile to Chinook salmon. Kilduff et al. (2015) reported that survival rates of Chinook and coho salmon released from hatcheries along the Pacific coast of North America have shifted coherence from the Pacific Decadal Oscillation (Mantua et al. 1997) to a geographically different sea surface anomaly, the North Pacific Gyre Oscillation. Inter-annual El Niño events are still seen as the proximal event influencing ocean survival, but the expression of El Niños in relation to North Pacific circulation has apparently changed since the 1980s. These changes also are reflected in the status of other marine species (Kilduff et al. 2015). Changing ocean currents are also reflected in the changing behavior and influence of in large-scale atmospheric circulation, which further influences marine food web productivity through advection and ocean deposition of continental dust that changes nutrient dynamics in the North Pacific Gyre (Letelier et al. 2019). Increasingly synchronous marine survival among numerous widely distributed salmon stocks suggests that more volatile Pacific-coast-wide fluctuations in salmon abundance are occurring (Kilduff et al. 2015).

The lack of marine survival and growth data for most wild stocks, including all Washington Coast spring-run Chinook, precludes a fuller understanding of the role their diverse life histories play in conferring resilience to fluctuations in ocean conditions. We do know as a rule that diversity of life history in salmon populations affords a critical buffer against such large-scale environmental variation (Schindler et al. 2010; Moore et al. 2010; Carlson and Satterthwaite 2011; Satterthwaite and Carlson 2015; Brennan et al. 2019).

### E. Diet

The diet of Chinook salmon varies depending on growth stage (Healey 1991). As alevins, young

Chinook rely on nutrients provided by the yolk sack attached to the body until leaving the redd after a few weeks. After emerging from the gravel, young Chinook fry begin to feed independently. Juveniles feed in streambeds before gaining strength to make the journey to the ocean. During this time, fry feed on terrestrial and aquatic insects and amphipods. As juveniles migrate toward the ocean, they may spend months in estuarine environments feeding on plankton, small fish, insects, or mollusks. Small fry feed primarily on zooplankton and invertebrates, while larger smolts feed on insects and other small fish, such as chironomid larvae, chum salmon fry and juvenile herring (Healey 1991). At sea, where the bulk of feeding and growth is done, adult Chinook typically feed on small marine fish, crustaceans, and mollusks (i.e., squid). Adult Chinook grow quickly in the estuary and gain body mass during their time at sea, building fat reserves that are required for upstream migration and spawning. During the upstream migration and holding in fresh water, adult Chinook do not feed or properly digest food, and thus they rely on stored energy (Quinn et al. 2016).

### F. Natural Mortality

Coastal spring Chinook salmon, like other salmon, are preyed upon by a wide variety of predators in freshwater and saltwater. However, their presence in freshwater as large-bodied adults during relatively low streamflow conditions makes them especially vulnerable to inland predators.

Other natural mortality factors about which little is known include disease, and natural catastrophes such as large natural landslides, earthquakes, and volcanic eruptions.

## III. Washington Coast Chinook Population Trends and Status

### A. General Population Trends and Status

All natural populations of spring-run Washington Coast Chinook salmon have declined sharply since the 1950s. Historically, spring-run Chinook salmon were abundant in most, if not all, major river basins on Washington's coast—from the Chehalis River in the south to the Hoh River in the north. These river basins are the Chehalis, Quinault, Queets, and Hoh. Although present in the Quillayute Basin, questions exist about their historical relative abundance there. The existing populations in these rivers are either entirely natural or have had a small component of hatchery fish, as in the Hoh River, except in the Quillayute system where substantial hatchery production exists.

A comparison of spring-run abundance trends seen in the Chehalis, Quinault, Queets, and Hoh rivers with available data is shown in Figure 2. Although differences exist in the abundance patterns among the populations, as discussed in the following sections, the preponderance of evidence demonstrates downward trends and an increasing risk of extirpations. The situation appears to be most acute in the Chehalis, Quinault, and Queets rivers—as discussed below. Note that the declining trend depicted for the Chehalis River is very likely much steeper than shown in Figure 2, as explained in the text that follows.

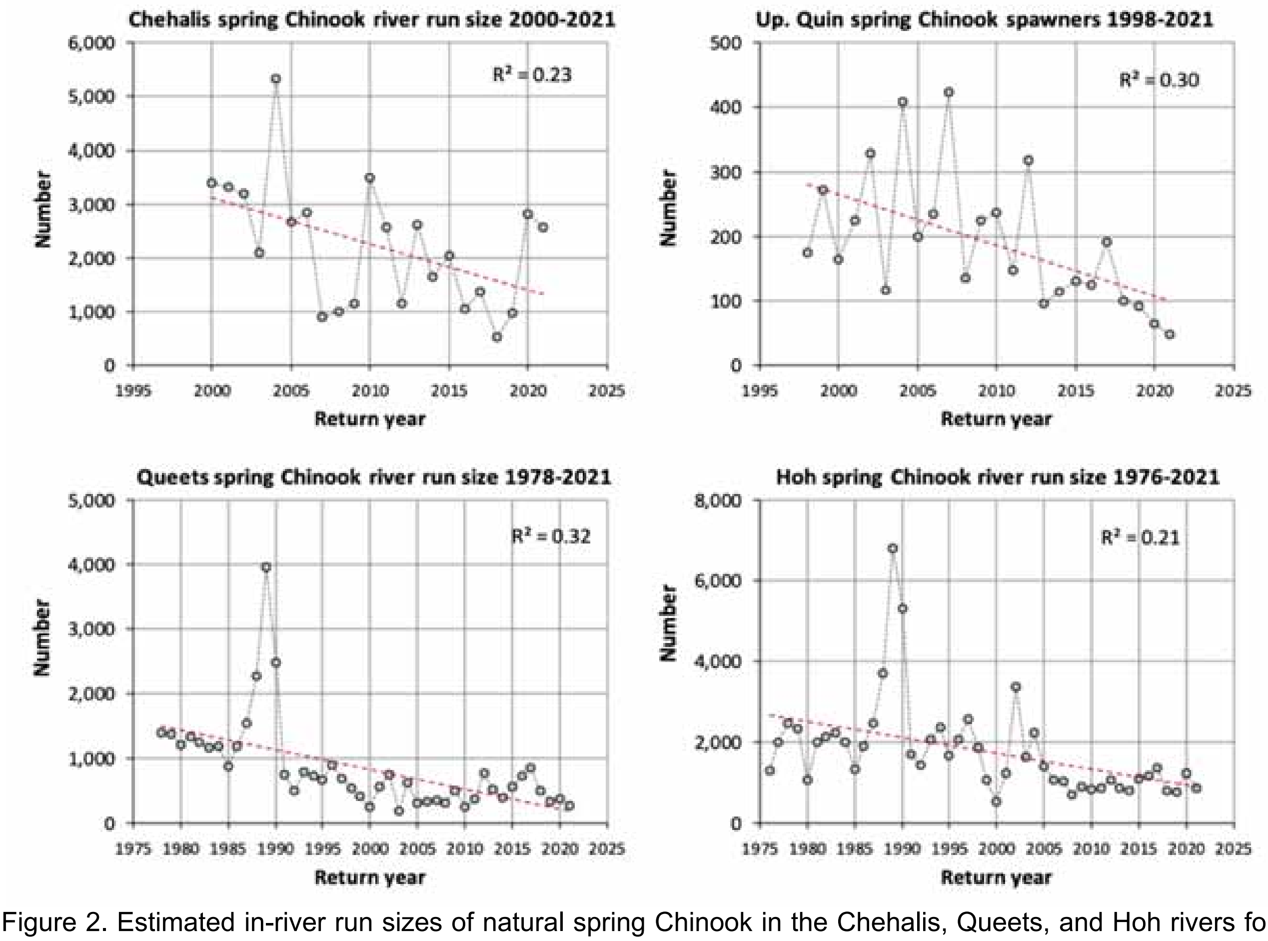


Figure 2. Estimated in-river run sizes of natural spring Chinook in the Chehalis, Queets, and Hoh rivers for years with consistent assessment procedures applied, and estimated spring Chinook spawners in the upper Quinault River, 1998-2021. Sources: PFMC database. Upper Quinault River data are from Quinault Indian Nation, unpublished data.

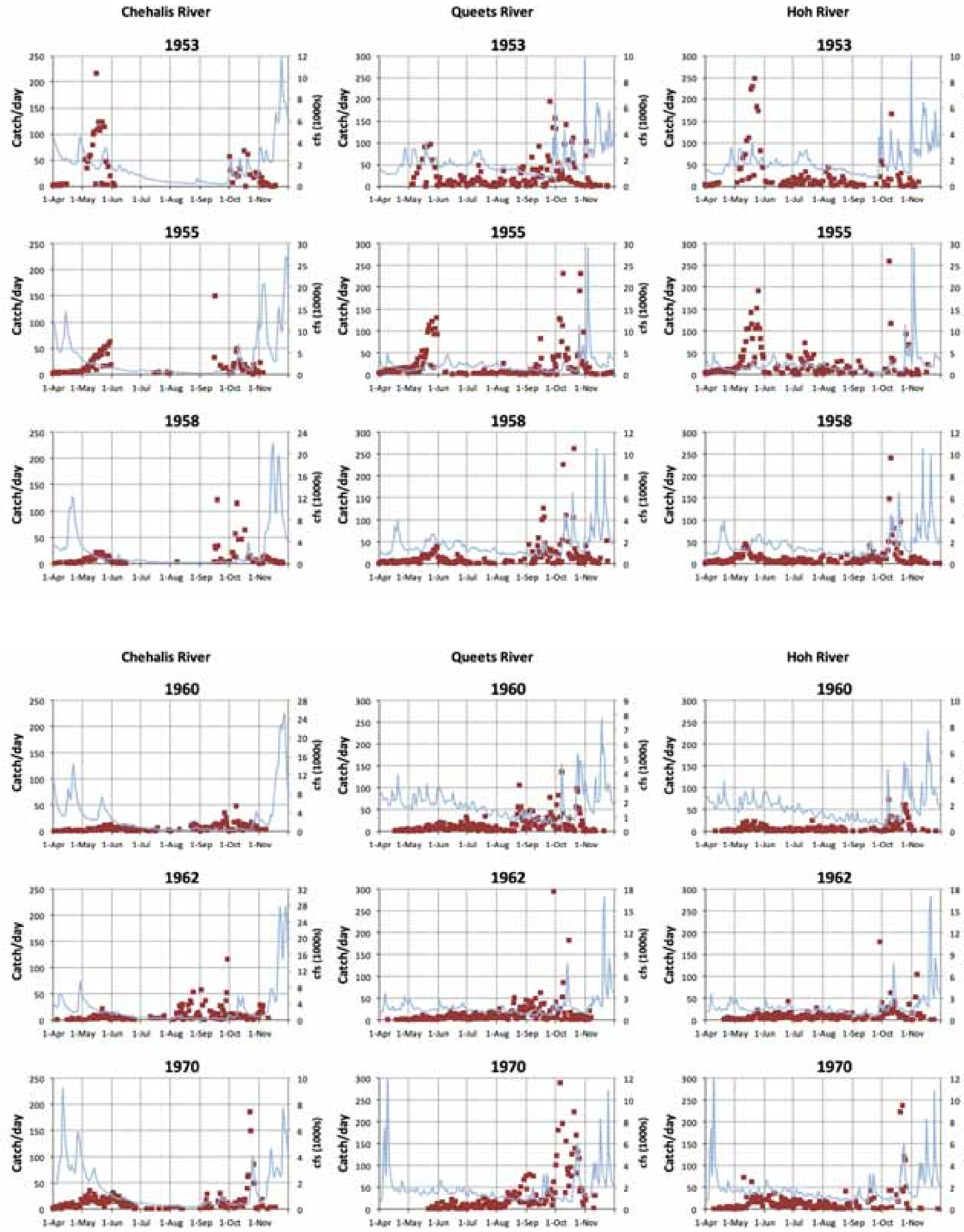


Figure 3. Daily reported catches of Chinook salmon between April 1 and November 30 for selected years from 1953 to 1970 in Indian gillnet fisheries in the Chehalis, Queets, and Hoh rivers (red squares). Years were selected that appeared to have limited data gaps in the records—see text. Mean daily stream flows (cubic feet per second; cfs) are also depicted (blue lines). Source: Washington Department of Fish and Wildlife catch records, Montesano, WA.

The earliest run component of the populations, i.e., those fish with timing characteristics of genetically homozygous spring-run Chinook (fish entering the rivers in April-June), is most severely depressed and most at risk. A review of relevant information follows.

Indigenous gillnet catch data from the early 1950s to the early 1970s demonstrate that the earliest run timing component most sharply declined during this period. Figure 3 plots daily commercial sales of Chinook salmon in the tribal fisheries in the Chehalis, Queets, and Hoh rivers for a set of years between 1953 and 1970.

The 1953-1970 period has the most complete set of daily sales data for these rivers in the years prior to 1974 when the U.S. vs. Washington federal court decision was made, which led to sweeping changes in salmon management in Washington State (Morishima 1984). Older monthly data, though with substantial data gaps, date back to 1935 for some of the coastal rivers but the oldest daily catch data begin in 1953. The daily sales data for these rivers and years are contained in bound volumes in the regional WDFW office in Montesano, Washington. While some gaps exist in the data record for these years (Wood 1984), they are sufficiently complete to provide a good representation of the temporal patterns of Chinook migration through the areas of the tribal fisheries in these rivers for these years.

To understand the patterns shown in Figure 3, some knowledge about how the fisheries were carried out is helpful. The tribal fisheries in the Queets and Hoh rivers are located in the lower several miles of those rivers, on or near the reservations in the vicinity of the river mouths (Mattson and Klinge 1976; Storm et al. 1990), while the fishery in the Chehalis River occurs on the Chehalis tribal reservation located at about RM 46-52 (Hiss et al. 1982). Indian commercial fishing in all of the major Washington coastal rivers throughout much or all of the 20th century was done using gillnets (Mattson and Klinge 1976; Wood 1984; Storm et al. 1990) at established set-net sites and also on some rivers by drift net (Mattson and Klinge 1976). Prior to the mid-1970s, the fisheries were open to a large extent year-round and usually for five or six days per week, depending on river and season (Larry Lestelle, Biostream Environmental, personal communication). The amount of fishing effort expended at any given time was self-regulating—when a lot of fish were moving through the fishing area, more fishers would work the fishery. Effort was low when few fish were moving through (Mattson and Klinge 1976).

The commercial sales of salmon on the rivers represent the minimum numbers of fish caught in any given period. Fish were also retained for ceremonial and subsistence purposes but, for much of the 20th century, no record was kept of these amounts. The number of fish retained per week for subsistence was probably relatively stable over a year within the reservation communities, though it did vary by species (Larry Lestelle, Biostream Environmental, personal communication). Therefore, when the number of salmon moving through a fishery was abundant, the percentage of the catch kept for ceremonial and subsistence purposes was low but it would increase substantially when few fish were moving through.

The plots in Figure 3 reflect the yearly patterns of adult Chinook salmon migrating through the tribal fisheries from 1953 to 1970. Notable changes in the patterns are evident over time. In the 1950s, a bimodal pattern is seen in the three rivers depicted. An early mode occurred during April to June, peaking in mid to late May in each river. This early mode is characteristic of pure spring-run Chinook salmon (Mattson and Klinge 1976). WDF (1952) listed the peak entry timing of spring Chinook salmon into each of the Washington coastal rivers as being between late May and early June based on the tribal gillnet data, though the end of April was given for the Quillayute population from very limited data. Note that this early component in the 1950s showed little correspondence to flow patterns.

A second, later mode, occurring between late August and early November, is seen in all of the plots over time for all years shown in Figure 3. Catches during these months are strongly influenced by flow levels. The fish in the Queets and Hoh rivers display a river entry pattern characteristic of north coastal fall-run Chinook salmon—peaks in entry from the ocean occur during freshets in late summer and fall (Larry Lestelle, Biostream Environmental, personal communication). The Chehalis tribal gillnet catches in these months show less correspondence to flow for unknown reasons but possibly related to the upstream location of the fishery (RM 46-52) and significant tidal influence in the lower 18 miles of the Chehalis River.

During the 1950s, the daily catches from mid/late June through mid-August generally dropped to low levels in all of the rivers, before increasing again as flows increased, usually in September. This pattern was particularly evident with Chehalis tribal catches, which essentially went to zero in mid-summer, most likely due to very low flows and high water temperatures in the Chehalis River in those months (Lestelle et al. 2019).

By 1970, the abundance of the earliest-timed component in the rivers had been reduced to very low numbers, as demonstrated by the sharp losses in tribal catches of these fish in the Chehalis, Queets, and Hoh rivers (Figure 3). In recent years in the Chehalis Basin, abundance of the early component is so low that even small tribal ceremonial and subsistence catches cannot be supported (Larry Lestelle, Biostream Environmental, personal communication). A similar situation exists in the Queets River.

The factors contributing to the declines of coastal spring Chinook populations vary by river basin, though habitat degradation has occurred to different degrees in all the basins, as described below. Reasons for the precipitous declines of the earliest run component prior to the mid-1970s, while later returning spring and summer Chinook salmon experienced a more gradual, longer-term decline, are not altogether clear. One factor that would have affected all the populations similarly was the rapid rise of ocean salmon fisheries, both commercial and recreational, during the mid-20th century (Kauffman 1951; PFMC 1978; Morishima and Henry 2000). In particular, the pattern of growth in the troll fishery off the Washington coast and how it may have impacted the early returning component of the spring run is most notable and described below.

Prior to the mid-1970s, management of ocean salmon fisheries—for both commercial and recreational fisheries—was virtually non-existent (Morishima and Henry 2000). Regulation, to the extent that it existed at all, was principally through the landing laws and licensing requirements of the states. There was no capability to limit participation by ocean fisheries outside of 12 miles from shore and only limited regulation within 12 miles. There were no limitations on the number of salmon that could be harvested. Participation in the fisheries was constrained principally by weather and market-driven size limits (Morishima and Henry 2000).

The catch of Chinook salmon by the Washington troll fishery increased from about 200,000 fish in 1935 to around 400,000 fish in the early 1950s (PFMC 1978). It is noteworthy that the 400,000 catch level was the all-time high catch for the Washington troll fishery. Although catches dropped to a low of 96,000 fish in 1965, they increased again to about 335,000 fish in 1976 (PFMC catch records). Since then, troll catches of Chinook salmon off the Washington coast have declined significantly as various management measures were put into place in efforts to improve regulation and reduce exploitation rates (Morishima and Henry 2000; PFMC catch records).

The distribution of the fishing effort, both spatially and temporally, along the Washington coast during the period of rapid growth of the troll fishery is relevant. Between 1935 and the mid-1950s, nearly half of the annual troll catch was consistently landed in the Grays Harbor district (Westport buying station located at the entrance to Grays Harbor), one of the four districts where troll catches are recorded on the Washington coast (Kauffman 1951; WDFW catch records, Montesano, WA). The other three landing districts are Ilwaco (Columbia River mouth), La Push (Quillayute River mouth), and Neah Bay (near the northwestern tip of the Washington coast). In 1953, approximately 186,000 Chinook salmon were landed in the Grays Harbor district.

Furthermore, Kauffman (1951) noted that the majority of the boats in the Washington troll fleet as it existed in about 1950 were “day boats”, meaning their landings represented one day of fishing. Thus, day boats were limited in how far they could go from their port. He further noted that the boats landing catches at Westport would work many miles north of the entrance to Grays Harbor and as far south as the Columbia River, though the southern fishing extent was usually off Willapa Bay. To the north, it is reasonable to assume that Westport boats could work to the vicinity of the Queets River or perhaps to the Hoh River. Day boats fishing out of La Push would similarly work north and south from that port. As a result, the day boats working out of Westport and La Push exerted fishing effort, more or less, all along the Washington coast off the mouths of the major rivers where spring Chinook salmon were returning to spawn.

The timing of the troll catch in mid-century is also relevant. For example, of the 186,000 Chinook salmon landed in Westport in 1953, nearly 30 percent of those were caught during April and over half were caught prior to June 1 (WDFW catch records, Montesano, WA). It is reasonable to believe that Washington coastal spring Chinook returning to their natal rivers from their primarily northerly migration would have been particularly vulnerable to the troll fleet working along the coast. The time of staging, and then entry to the rivers, by these fish would have coincided with the highest monthly troll catches over many years. Similar to the pattern in 1953, about half of the troll-caught 237,000 Chinook salmon landed in Westport in 1974 were landed in April, May, and June and most were caught in May (WDFW catch records, Montesano, WA).

While the Washington troll fishery likely had the more significant effect compared to the ocean recreational fishery on the returning early component of the populations in the 1950s, it bears noting that the recreational fishery was growing rapidly from the 1950s to the 1970s. PFMC (1978) reported that the ocean recreational catch of salmon in Washington increased rapidly after 1952, sometimes exceeding the total marine sport salmon catch for all other Pacific Coast states and British Columbia combined. At the time of that publication, the ocean Chinook salmon catch had increased since 1952 at a rate of approximately 7,000 fish per year and reached a peak of 262,000 Chinook salmon in 1975 after a low of 38,000 fish in 1953.

The harvest rates during this period by the combined troll and recreational fleets fishing along the Washington coast were likely high on coastal spring Chinook populations. Due to their river return timing, the harvest rates may have been most significant on the early component of the populations. It is reasonable to assume that these ocean harvest rates, combined with the in-river harvest rates (e.g., Wood 1984), both by the tribal gillnet and the non-tribal river sport fisheries, exceeded sustainable levels.

Moreover, it is reasonable to also assume that the effects of such harvest impacts disrupted the population structure of Chinook salmon in the coastal rivers. The changes in the river entry timing patterns seen over time in the plots shown in Figure 3 suggest that as the early-timed component was declining in the Queets and Hoh rivers, the proportion of the aggregate Chinook populations comprised of summer-timed and fall run fish would have been increasing. Such changes may have facilitated an increase in interbreeding between the run types in the rivers, which would have likely contributed to the declines in the spring Chinook populations (Thompson et al. 2019a).

A recent assessment of run-type genotypes in the upper Chehalis River basin has shown that only a very small percentage (<5 percent) of pure spring Chinook (homozygous for the GREB1L gene) currently remains in the aggregate Chinook population in that river system (Gilbertson et al. 2021). That assessment shows that the declining trend of spring Chinook salmon in the Chehalis River is very likely much steeper than depicted in Figure 2. It suggests that estimates of spring Chinook salmon abundance in that river, which are based on redd counting and assumptions about the run type of the spawners, are biased high—probably by a substantial amount. The assessment shows relatively high abundance of Chinook salmon that are heterozygous for the GREB1L gene, indicating a high incidence of interbreeding between run types (Thompson et al. 2019b).

The focus here on the Washington ocean fishery impacts during the mid-20th century is meant to understand what likely contributed to the sharp declines of the early run component of these populations. As discussed above, the very extensive and intensive fisheries from Washington to Alaska that rapidly developed during the second half of that century have very likely been a principal factor contributing to the overall decline of these populations. But the spatial and temporal patterns of the fisheries along the Washington Coast were likely a major factor that affected the early spring component of this population in particular.

### B. Chehalis River Basin

*"The history of the Chehalis Basin fish run and habitats is one of pristine productivity, then gross degradation."* – Chehalis River Basin Fishery Resources Status, Trends and Restoration, Hiss and Knudsen (1993)

The Chehalis is the largest river basin within the Washington Coastal Chinook ESU. It is also the watershed with the most compromised habitat and concentrated anthropogenic effects within the ESU. The Chehalis River flows approximately 125 miles in southwestern Washington north-northwesterly to Grays Harbor and the Pacific Ocean. The Chehalis River Basin is the second largest basin in Washington State. It is bounded on the west by the Pacific Ocean, on the east by the Deschutes River Basin, on the north by the Olympic Mountains, and on the south by Cowlitz River Basin. The basin includes portions of Grays Harbor, Lewis, Mason, and Thurston Counties and the Cities of Aberdeen, Centralia, Chehalis, and Hoquiam, and the Confederated Tribes of the Chehalis Reservation. Human population in the Chehalis River Basin was about 141,000 in 2000.

The basin encompasses approximately 2,700 square miles and has more than 3,400 perennial stream miles. The physical diversity of the basin historically gave rise to a high diversity of aquatic species—it was historically extremely productive for salmonid species, including spring Chinook salmon. Ten ecological regions have been identified in the basin based on distinct ecological characteristics (ASRPSC 2019). These regions span a very large diverse area, draining parts of the southern Olympic Mountains, Black Hills, foothills of the Cascade Mountains, and the Willapa Hills.

The natural resources of the Chehalis Basin have supported native peoples for thousands of years and continue to provide for both tribal and non-tribal people of the basin. The basin supports the cultures of two federally recognized tribes, the Confederated Tribes of the Chehalis Reservation and the Quinault Indian Nation. The Quinault Indian Nation (QIN) was party to the signing of the Quinault River Treaty of 1855 (also known as the Treaty of Olympia of 1856[1]), in which their rights to maintain their fisheries in their usual and accustomed fishing places were recognized and preserved. Today, QIN is a co-manager with Washington State of the fisheries-related resources in the Chehalis Basin, including the water and habitats that support those

---

[1] Governor Stevens officially signed the treaty in January of 1856 in Olympia; thus the treaty is sometimes referred to as the Treaty of Olympia.

resources, as recognized through the federal court case U.S. vs. Washington in 1974.

Over the past roughly 150 years, the natural ecosystem of the basin has been substantially altered. These changes have resulted from intensive and extensive timber harvest practices, land clearing, stream channel modifications, dam construction, agriculture, urbanization, ruralization, and industrialization (ASRPSC 2019).

As a result of these threats, all salmonid species in the Chehalis basin have substantially declined from historical levels (ASRPSC 2019). The situation is most severe for spring-run Chinook. McConnaha et al. (2017) and ASRPSC (2019) presented evidence showing that without meaningful actions to prevent further loss, spring Chinook will likely be extirpated from the Chehalis basin by the end of the century. Arguably, extirpation will come much sooner based on the projections in those documents.

### 1. Population Trends and Status

Historically the Chehalis Basin likely hosted the largest spring-run Chinook population on the Washington coast based on the number of stream miles documented to have been used by spawners of this run-type. Spawning aggregations of spring Chinook salmon existed in the tributaries—upper Wynoochee River, Skookumchuck River, Newaukum River, and South Fork Chehalis River—and the mainstem Chehalis River (RM 33.3 to 67.0 and RM 81.3 to 113.4) and its forks (WDF 1958; Phinney and Bucknell 1975; Weyerhaeuser 1994; ASRPSC 2019), as well as in the larger tributaries to these rivers; some spawning occurs in the Black River and in Elk and Stillman Creeks (Kliem and Holden 2011). Some evidence exists that they may have also occurred in the Satsop River system (WDFW and WWTIT 1994; Lestelle et al. 2019).

Historical spring Chinook abundance information prior to the late 20th century for the Chehalis Basin is not available. Early fishery records suggest that the total aggregate Chinook population in the basin may have been as high as 84,000 fish in 1914 based on cannery packs (Cobb 1930), that was likely dominated by fall Chinook. There were several canneries, fish traps, and troll and gill net fisheries in Grays Harbor, and tribal set net fisheries were conducted for spring and fall Chinook by the Chehalis Indian fishery on the Chehalis Indian Reservation.

Historical fishery records suggest that the Chehalis spring Chinook population could have been the largest coastal run of spring Chinook in Washington. WDF records list 4,647 spring Chinook harvested by the Chehalis tribe in 1948 (WDFW Coastal Investigations 1951-58). Annual catch records from the 1930s and 1940s are incomplete with obvious data gaps, and it was noted that in 1953 the Chehalis Indian fishery for spring Chinook was curtailed for personal use at some point during the season (WDF catch records, Montesano, WA). Still, WDF records show about 2,200 spring Chinook were caught (and presumably sold) that year (WDF catch records, Montesano, WA).

Daily catch records of spring Chinook for the Chehalis Tribal fishery exist for most years from 1953 to 1970. The average annual catch of fish for the months of April to August, based on daily sales, was 1,390 Chinook. Figure 3 displays the temporal patterns of the catches by year.

By the 1950s, the abundance of spring Chinook salmon in the Chehalis Basin was undoubtedly severely depleted. Most, if not all, coastal streams had been significantly degraded due to impacts from: logging; pollutants from timber and pulp mills; channelization of the river and major tributaries; filling of wetlands for agriculture; an aggressive commercial troll fishery in Grays Harbor and off the Washington Coast; and more than 100 splash dams built for logging without fish passage (Hiss and Knudsen 1993). Wendler and Deschamps (1955) stated, for example, "Splash dams located at Doty and Dryad although far upstream from the mouth of the Chehalis River, blocked off one of the major spring Chinook producing areas in the river system." (Doty and Dryad are located approximately at river miles 97 and 94, respectively.)

Historical, pre-contact salmon abundances for the Chehalis Basin have been estimated based on an Ecosystem Diagnosis and Treatment (EDT) model (McConnaha et al. 2017; ASRPSC 2019), which estimated equilibrium abundance of spring Chinook (i.e., an average value) at approximately 27,000 spawners. The number represents the number of spawners that would have occurred in the absence of all fisheries. The model estimated abundance of fall Chinook spawners in all streams upstream of Aberdeen at 137,000 fish, and approximately 16.5% of the total Chinook production upstream of Aberdeen was estimated to be spring Chinook salmon. (Note: the modeling was done assuming that no spring-run fish were historically produced in the Wynoochee or Satsop systems.)

The co-managers for the Chehalis River basin (Washington State and QIN) manage spring Chinook as a separate population from fall Chinook salmon. Allozyme analysis has shown Chehalis spring Chinook, represented by fish from the Skookumchuck River, to be genetically distinct from Chehalis fall Chinook (Marshall et al. 1995, as cited in Kliem and Holden 2011). Hatchery-origin spring Chinook were released into the Wynoochee River in the mid-1970s, but it is unlikely that there was any hybridization with the existing native stock (Kliem and Holden 2011). There is currently no hatchery production of spring Chinook salmon in the basin. Hatchery production of fall Chinook salmon occurs in the Humptulips, Wishkah, Wynoochee, and Satsop subbasins; all of these areas are located in the lower half of the Chehalis River basin.

Figure 4 depicts estimated run sizes of wild spring and fall Chinook salmon returning to the Chehalis Basin upstream of Aberdeen (excluding streams entering Grays Harbor downstream of Aberdeen) for years when consistent assessment methods were used by the co-managers. It is important to recognize, however, that abundance estimates for spring Chinook made prior to 2000 are not directly comparable to those beginning in 2000 due to changes in stream coverage used in spawner surveys (Lestelle et al. 2019). The fall Chinook abundance estimates in Figure 4 (middle) exclude hatchery produced fish. The figure does not include estimates of natural fall Chinook returning to the basin upstream of Aberdeen for the years 2020 and 2021 because those data were not available to the petition authors.

Atlas et al. (2023) calculated the mean spring-run Chinook salmon spawner escapement in the Chehalis River basin from 1980 to 2019 was 1,708 fish. Beamesderfer (2021) summarized natural origin spawner abundance of Chinook salmon in the Chehalis basin from 2011-2020, which annually averaged 16,200 fall-run, 1,600 spring-run, and 30 Chinook classified as summer-run.

Figure 4 (top) shows a significant ($P<0.05$) declining trend for the abundance of spring Chinook adults in the basin since 2000. As noted earlier, however, the trend is likely steeper than shown in the figure because of the likelihood that spawners of this run-type are overestimated in recent years, likely by a substantial amount. Genetic analysis of emergent Chinook fry in the upper Chehalis Basin shows that abundance of the run-type is much less than indicated by spawner surveys using the standard spawner assessment approach (Gilbertson et al. 2021). As discussed below, there is reason to believe that the older data (e.g., 2000-2010) in Figure 4 (top) may more accurately reflect the actual spring Chinook abundance in those years likely because of apparent less interbreeding with fall Chinook in those years (Thompson et al. 2019b).

It bears noting that the trend in Figure 4 (top) does not necessarily reflect the trend for ocean run sizes of Chehalis spring Chinook that might be seen if ocean run size data were available. Ocean run sizes estimated in adult equivalents (AEQ) are those that would be expected to return to the

Chehalis Basin in the absence of ocean fisheries. No estimates exist for ocean AEQ run sizes of Chehalis spring Chinook, or for the other coastal populations for this run type, for the years shown in the figure.

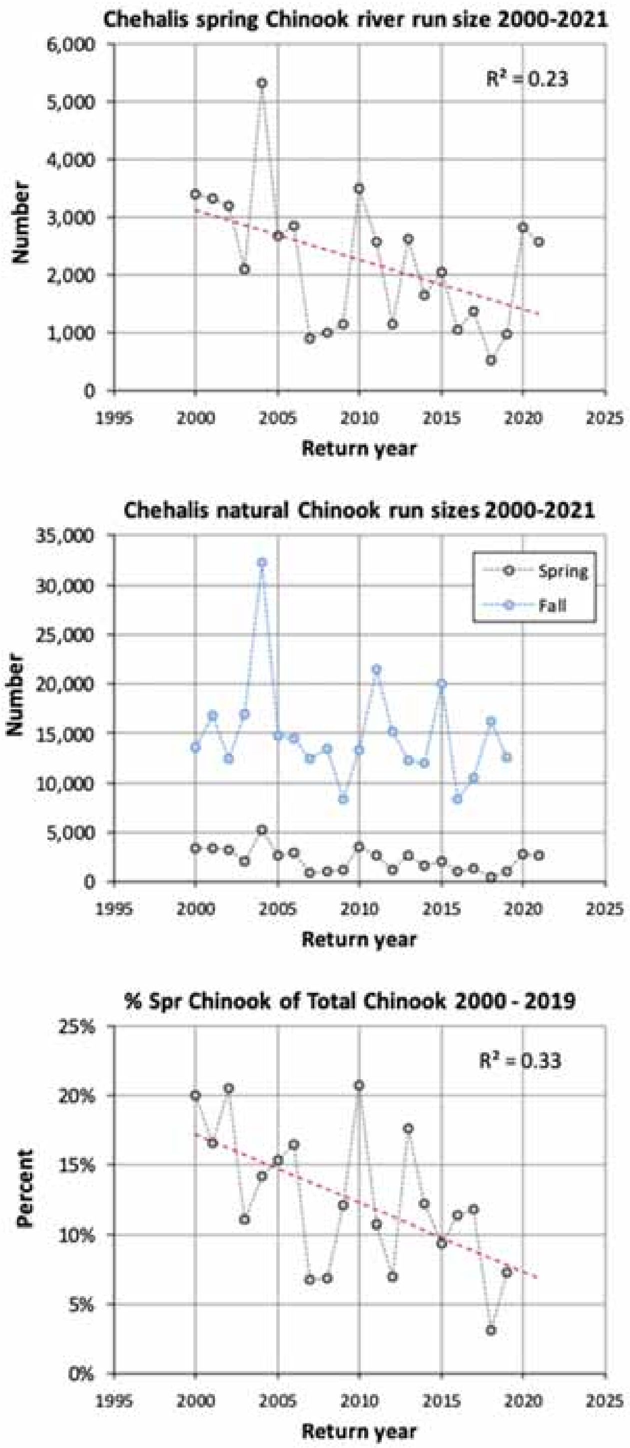


Figure 4. Top – Chehalis Basin estimated spring Chinook in-river run sizes, 2000-2021; middle – numbers of natural Chinook (spring and fall) returning to the Chehalis Basin upstream of Aberdeen (2000-2019/2021); bottom – percentages of total natural aggregate Chinook run sizes comprised of spring Chinook salmon. Sources: co-manager databases provided to petition authors.

Similarly, no estimates exist of ocean exploitation rates (ERs) for Chehalis spring Chinook. It is reasonable to assume, however, that they may be similar to exploitation rates for Washington coastal fall Chinook populations to an extent due to their common ocean-type life histories and presumably similar northerly migrations along the continental shelf. Wood (1984) presented data, though limited, that showed similar ocean catch distributions for Hoh spring Chinook and Washington north coastal fall Chinook. The fall-run populations are far-north migrating, being caught primarily in the coastal waters of British Columbia and southeast Alaska (Myers et al. 1998; Weitkamp 2010; CTC 2023).

Because no estimates are available for ocean ERs on Washington coastal spring Chinook populations, useful information can be inferred from available data for an exploitation rate indicator stock representative of coastal fall Chinook. The Chinook Technical Committee (CTC) of the Pacific Salmon Commission uses coded wire tagged (CWT) indicator stocks to assess ocean migration patterns, survival rates, and ocean and total ERs. The Queets River fall-run population serves as an exploitation rate indicator stock for Washington north coastal fall Chinook. Starting with brood year 1977, juveniles produced each year from wild Queets River fall Chinook and reared to release size in a hatchery have been annually coded wire tagged and released to monitor exploitation rates (HSRG 2004; CTC 2023). Results from the Queets fall-run indicator stock tagging are helpful for interpreting the trends seen in Figure 5, as well as the trends discussed in sections below for the other north coast spring Chinook populations. Patterns of the spatial distribution and fishery exploitation rates relevant to this petition are described briefly below:

- Beginning with brood year 1982, estimated total ERs, including incidental mortalities and combined harvests in the ocean and the terminal river, show no obvious trend (Figure 5). ERs for brood years in the late 1970s to 1981 were somewhat higher than rates since then. Over the past 14 brood years, total ERs for this stock have ranged between about 50 to 70 percent, averaging about 60 percent. CTC (2023) notes that across its 38 complete brood years, the total brood year ER for this stock has averaged 59 percent, ranging between 37 and 82 percent, but has not displayed any obvious or notable temporal trends.

- The large majority of fishery-related mortalities on this stock occurs in waters along British Columbia and southeast Alaska. Since 1981, over 70 percent of the annual total AEQ fishery-related mortality has occurred within these waters (data from Appendix C46 in CTC [2012] and Appendix C28 in CTC [2023]). No obvious trend is evident in the percentage of fishery mortalities that occurred there since 1981.

- Of the total annual AEQ fishery related mortality on this stock since 1981, the Queets River terminal area fishery is responsible for an average of 28 percent (data from Appendix C46 in CTC [2012] and Appendix C28 in CTC [2023]). No obvious trend over time is evident in the percentage of fishery mortalities that occur in the terminal area fishery.

- The time series-wide mean survival for the Queets indicator stock from release to age 2 has averaged 2.55 percent, among the highest for all ocean-type exploitation rate stocks in Washington analyzed by the CTC (2023, page 27). (It is noted that this indicator stock is the only one that uses wild natural-origin parents every year in the program.) There is little or no evidence of any temporal trend in the time series for survival to age 2.

- The returns of Queets fall Chinook to the river since the 1970s has been generally stable, showing no obvious temporal trend (see Figure 8 below), similar to the run size pattern for fall Chinook in the Chehalis Basin (Figure 4 - middle). A similar pattern is also evident for the Hoh fall

Chinook in-river run sizes (see Figure 9 below). These patterns for the Washington coastal fall-run types indicate that the fall runs are sustaining themselves at productive levels over recent decades despite changes in freshwater habitat conditions that have occurred and relatively high total fishery exploitation rates.

In contrast to the pattern seen for Chehalis fall Chinook, the declining trend for Chehalis spring Chinook (Figure 4) indicates that mortality from all sources combined exceeds the productive resilience of the spring-run type to sustain itself. Mortality factors include harvest and environmental effects, combined with the effects of interbreeding among the run-types.

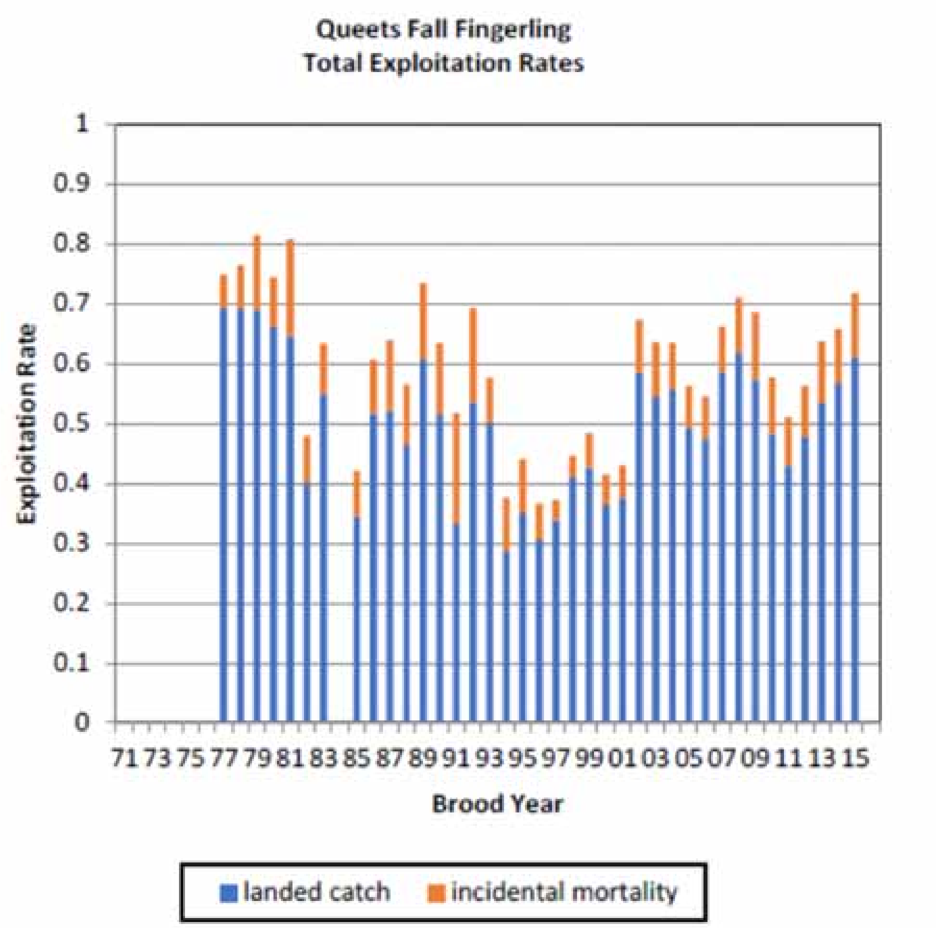


Figure 5. Brood year total exploitation rate in terms of landed catch and incidental mortality for the Queets fall-run indicator stock, brood years 1977 – 2015. Source: CTC (2023) – Appendix D8.

Chehalis spring Chinook can reasonably be assumed to be subjected to similar ocean harvest pressures seen in Figure 5, though likely at somewhat lower rates due to their homeward migration occurring earlier, thereby missing some exploitation in their final ocean year. It bears noting that terminal area harvests have been essentially eliminated on Chehalis spring Chinook in recent years.

The bottom chart in Figure 4 shows a sharp decline in wild spring Chinook returning to the Chehalis Basin since 2000. This is further evidence that population structure of the aggregate Chinook salmon population has changed significantly over a relatively brief period of years.

A change in population structure of Chehalis Basin Chinook salmon is evidenced by the significant losses, including likely extirpations, of spring Chinook spawners in various subbasins. Spring Chinook spawners, which were well documented in the upper Wynoochee River in the early and mid-1950s (WDF 1955), were extirpated from that subbasin around the time of the construction of the Wynoochee Dam in 1972 (ASRPSC 2019).

At the time of publication, Phinney and Bucknell (1975) reported that spring Chinook spawners utilized the North Fork Newaukum River, South Fork Chehalis River, and the upper mainstem Chehalis River. Recent WDFW spawning records and Ronne et al. (2020) show few spring Chinook spawners using those areas. More recent genetic analysis of Chinook fry captured in those areas indicate substantially fewer true spring Chinook are being born in those streams (Gilbertson et al. 2021). Extirpations in the South Fork Chehalis River and upper Chehalis River appear to be imminent, and may have already occurred.

In addition, there are very few true spring Chinook in the Skookumchuck River. Before Skookumchuck Dam was built in 1970, spring Chinook spawned primarily in the upper river (i.e., upstream of the dam site at RM 22) (Finn 1973). The dam was built with no provision for passing salmon upstream. While WDFW spawner surveys continue to record a substantial number of Chinook spawning by fish believed by WDFW surveyors to be spring Chinook, genetic analysis of fry indicate only a very small percentage are true spring Chinook (<5%) (Gilbertson et al. 2021). The genetic analysis also shows that a substantial percentage of fry are heterozygous for the GREB1L gene, which indicates that interbreeding between run-types has been significant in the Skookumchuck subbasin.

The blocking of upstream passage by the Skookumchuck Dam, combined with changing the flow regime in late summer due to reservoir operations (USGS flow records), appear to have facilitated the hybridization of run-types in the subbasin. Reservoir operations altered the natural flow regime, significantly increasing late summer flows. Prior to dam construction, summer flows commonly dropped to 30 cfs or lower. Once operational, the dam frequently raised summer flows to over 90 cfs and often exceeded 120 cfs. These unnatural increases in late summer flows likely facilitated an increase in early arriving fall Chinook salmon moving into the Skookumchuck River, as well as of heterozygous hybrids (intermediately timed), leading to continued dilution of the pure spring Chinook population that once inhabited the river.

All of these changes in the population structure of the aggregate Chinook runs in the Chehalis Basin have resulted in a substantial reduction in the spatial structure (distribution) of spring Chinook salmon in the basin. Spatial structure is an important characteristic of a salmon population that determines its long-term viability and extinction risk (McElhany et al. 2000).

Further, WDFW spawning surveys conducted since the early 1980s in the Skookumchuck, Newaukum, and upper Chehalis rivers clearly demonstrate that spawn timing of fish considered to be spring-run Chinook salmon has been progressively getting later (Figure 6; Zimmerman 2017). In the 1980s, peak spawn timing in all of these rivers occurred in mid to late September. Since 2010, however, peak spawn timing was recorded as being in early to mid-October. The more recent timing overlaps significantly, or coincides, with spawners believed by WDFW surveyors to be fall Chinook salmon (Lestelle et al. 2019). This change in timing is indicative of a breakdown in population structure that historically would have maintained spawning separation between the run-types needed by spring Chinook salmon (Thompson et al. 2019a). And it helps explain the low percentages of fry identified as homozygous for the GREB1L gene in all these areas in the study by Gilbertson et al. (2021), while relatively high percentages of heterozygous fry were found.

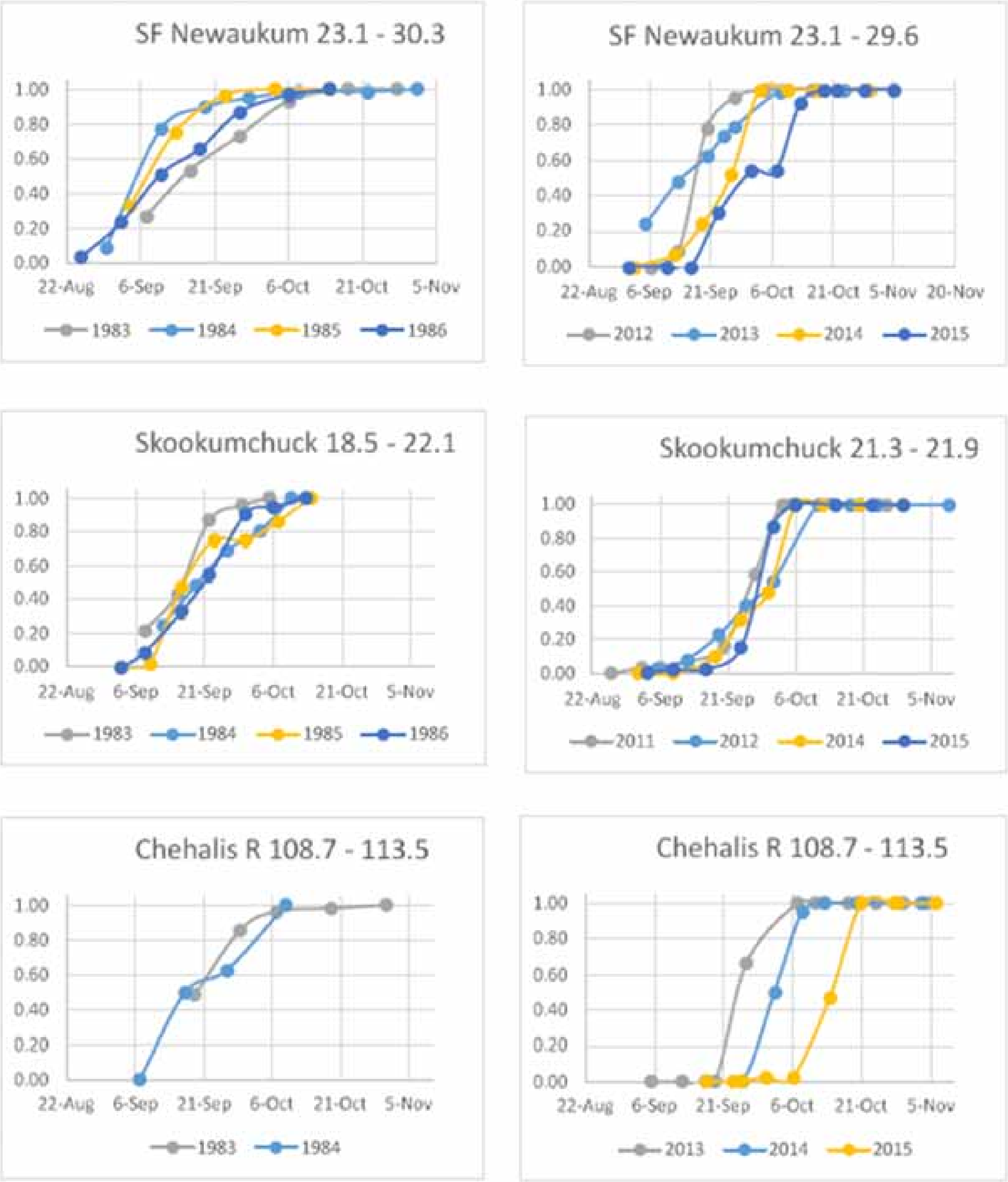


Figure 6. Changes in the cumulative proportions of salmon redds classified as belonging to spring Chinook salmon observed by week in three index areas of the upper Chehalis Basin. Spawn timing is shown for two time periods (1980s, recent) that bracket the available time series over three decades (1983-1986 and 2012-2015). Taken from Zimmerman (2017).

## 2. Threats

There are numerous threats to spring Chinook salmon in the Chehalis Basin, which exist both within the basin and outside the boundaries of the basin. Within the basin, threats include: legacy impacts and continued degradation of freshwater and estuarine habitats; increased predation by exotic species and pinniped species; pollution; interactions with hatchery fish; poaching; increased hybridization with fall Chinook salmon; a proposed new dam in the upper basin; and increasing effects of climate change. Threats beyond the basin include: effects of fishing by coastal and offshore marine fisheries; and changes in ocean productivity due to climate change. The cumulative effects of these threats pose a critical risk to the persistence of spring Chinook salmon in the Chehalis basin.

### a. Harvest

Harvests directed at Chehalis spring Chinook within the river by both tribal commercial and non-tribal sport fisheries ended several years ago. The Chehalis tribal ceremonial and subsistence fishery has also essentially ended, though some extremely limited take may still occasionally occur. There may remain some impacts from sport fisheries directed at other species, through bycatch of Chehalis spring Chinook. Some poaching also likely occurs, as documented in Liedtke et al. (2016). Significant harvest-related mortality likely continues to occur in ocean fisheries. Chehalis spring Chinook are very likely caught in commercial and recreational fisheries off the coasts of Washington, British Columbia, and Alaska, although the main impacts are expected to occur north of the Washington-BC border, as described above. Chehalis spring Chinook can reasonably be assumed to be subjected to similar ocean harvest pressures seen in Figure 5, though likely at somewhat lower rates. Total brood year AEQ ERs on the Queets River exploitation rate indicator stock for fall Chinook has averaged about 60% over a period of decades and demonstrate no indication of decline over time (CTC 2023). Those ERs include terminal in-river harvest but the large majority of the harvest impacts occur in the ocean. The ocean fisheries are not managed in a manner to limit impacts on declining Washington coastal spring Chinook populations.

### b. Habitat Degradation

With the arrival of Euro-Americans to the Chehalis Basin, extensive changes to the freshwater and estuarine habitats began over 150 years ago (Storm et al. 1990). Most land in the basin is in private or state ownership for timber harvest and agriculture, with some managed by the U.S. Forest Service. Consequently, almost all of the landscape has been altered by intensive logging, continued forest management, land clearing, and agriculture (ASRPSC 2019).

During the first wave of logging that began over 100 years ago, splash dams were built in most of the larger streams to move logs downstream to mills along Grays Harbor (Wendler and Deschamps 1955; Storm et al. 1990). Later in the 20th century, an extensive network of roads was built across the landscape, nearly to the ridgetops of the basin, to facilitate the removal of remaining old growth, which has been followed by on-going forest management and logging to the present time (ASRPSC 2019). These activities resulted in the nearly complete removal of large wood structure within the thousands of miles of streams, large and small, including in all of the streams used by spring Chinook salmon. As a result, bed scour of spawning habitats has been severe and extensive (Weyerhaeuser 1994; Smith and Wenger 2001) and continues (ASRPSC 2019). Bed scour has likely been most severe in the upper parts of the stream systems, where stream gradients are higher, which were the areas in the river basin most heavily used historically by spring Chinook salmon (Phinney and Bucknell 1975; Weyerhaeuser 1994; Lestelle et al. 2019).

Channel incision, caused by the loss of wood structure combined with stream channelization in some areas, is a particular problem in the Chehalis basin (Smith and Wenger 2001). The issue is especially severe in the upper Chehalis River, in the South Fork Chehalis River, and in some parts of the Newaukum and Skookumchuck rivers (ASRPSC 2019)—areas where historical spring runs of Chinook salmon occurred. Incision has worsened bed scour and disconnected the stream channels from the floodplains.

Sedimentation of salmon spawning grounds in the Chehalis Basin has been extensive due to logging, forest management, agricultural activities, and urbanization (Smith and Wenger 2001; ASRPSC 2019). The widespread road networks throughout the subbasins associated with these activities, as well as related landslides from logging roads, have produced and continue to produce high fine sediment loads that suffocate incubating salmon eggs in the basin (McConnaha et al. 2017; Beechie et al. 2020).

These same activities have decimated the riparian corridors of hundreds of miles of streams in the basin (Smith and Wenger 2001; ASRPSC 2019). While riparian zones now receive some protection within forest management areas, particularly on larger streams, many miles of stream corridors lack riparian vegetation within agricultural areas. Shading in these areas is almost completely, or entirely, lacking. Consequently, extensive stream miles are subject to very hot water temperatures in summer, often exceeding Washington State standards, and sometimes exceeding lethal levels for salmonids (Smith and Wenger 2001; ASRPSC 2019). Fish kills associated with high temperatures have occurred (Lestelle et al. 2019), as recently as 2021, and these events have on occasion been particularly severe on spring Chinook adults in the upper Chehalis basin (Kohn et al. 2009; Lestelle et al. 2019). Climate change is projected to substantially worsen these conditions. Without major, successful restoration efforts that address temperature, the outlook for spring Chinook salmon in the basin is grim (McConnaha et al. 2017; ASRPSC 2019; Beechie et al. 2020; Winkowski and Zimmerman 2020).

Streams in the upper Chehalis Basin—those originating in the Willapa Hills and Cascade Mountains ecological regions—are primarily rainfall fed and are subject to extremely low flows in late summer (ASRPSC 2019). These ecological regions are the ones that most recently have continued to support spring Chinook salmon. Water withdrawals in these areas to support agriculture, municipalities, and urbanization have substantially exacerbated summer low flows (Phinney and Bucknell 1975; Smith and Wenger 2001; ASRPSC 2019; NHC 2020). Climate change effects can be expected to worsen these conditions.

As part of the Chehalis Basin Salmon Habitat Restoration and Preservation Strategy, limiting factors for Chinook salmon and habitat degradation were summarized for the sub-watersheds within the Chehalis basin Kliem and Holden (2011). In the Skookumchuck River, riparian condition for the lower reaches is considered to be in poor condition, due to logging, agriculture, urban development; and the TransAlta dam at RM 21.9 blocks 3.6 miles of Chinook habitat. In the Newaukum River, there is poor riparian habitat due to conversion from forestland to agriculture and rural residences; the mainstem Newaukum is on the 303d List for high temperatures and fecal coliform, due to livestock and failing septic systems; and there is high amounts of sediment due to livestock and high road densities. The South Fork Chehalis River has impaired riparian habitat, erosion, and sediment due to agriculture, logging, and roads; and fish passage is limited by barrier culverts. In the mainstem Chehalis River, there has been riparian vegetation loss and reduced shade canopy due to urbanization and agriculture; and poor water quality, with many reaches in the Chehalis Mainstem on the 303d list for temperature, fecal coliform, and dissolved oxygen, due to livestock, dairies, urban stormwater and sewage discharge. The Black River has poor water quality, due to a deep stretch with naturally low dissolved oxygen levels that is magnified from land use practices along the river (pollution from dairy farms) which became apparent during the 1989 Black River fish kill, which resulted in the death of adult Chinook salmon. The lower nine miles of the mainstem Black River have “poor” riparian habitat and bank erosion sites throughout watershed due to livestock; and flows are impaired due to fish farming practices, loss of water from a pipeline crossing, heavy water withdrawals for irrigation, gravel mines, all of which contribute to poor instream flows for fish, below set minimum instream flows. Elk Creek has extensive erosion due to high road density and poor riparian conditions due to logging. Stillman Creek suffers from sediment due to roads; fish passage is limited by barrier culverts; and the lower part of Stillman Creek is on the 303d List for high temperatures.

Various kinds and sizes of dams have been built and operated in the Chehalis basin for over a hundred years, most of which were not built to pass salmon species. The scores of splash dams built in the early 20th century had significant effects on habitat characteristics and fish runs (Wendler and Deschamps 1955). In 1970 and 1972, when the Skookumchuck Dam and Wynoochee Dam were built, access to the upper reaches in those rivers was blocked to spring Chinook (ASRPSC 2019). Those dams continue to block access; the best habitat in those areas lies underneath the reservoirs formed by the dams. As noted earlier, the Skookumchuck Dam also significantly changed the summer flow regime in that river, which likely facilitated spring and fall Chinook hybridization downstream of the dam.

A large new dam has been proposed for construction on the upper mainstem Chehalis River. Following a major flood in 2007, the Chehalis River Basin Flood Control Zone District proposed to construct a flood retention facility and associated temporary reservoir upstream of the town of Pe Ell at approximately RM 108 (Ecology 2020). The dam would be designed to hold back flows during periods when flows exceed a threshold level, intended to ameliorate flooding downstream. The temporary reservoir formed would inundate more than 6 miles of the upper mainstem river and the lower reaches of several major tributaries. The area of inundation would encompass major historical spring Chinook spawning grounds in the upper river (Phinney and Bucknell 1975; Weyerhaeuser 1994). From 2013-2018, 93-100% of spring Chinook that spawned in the Upper Chehalis spawned within the proposed dam inundation footprint (Ronne et al. 2020). The dam and its operations would have significant adverse effects on any remaining spring Chinook that use reaches upstream of the dam as well in reaches downstream (WSDE 2020, ACOE 2020). It is expected that the dam would extirpate the remaining Chinook run that utilizes those areas. Washington Department of Ecology (2020) acknowledges the dam project would have significant impacts on both spring-run and fall-run Chinook salmon in the Chehalis River basin. WDOE modeling predicts declining numbers of salmon into the future with the proposed project and reduction of the genetic diversity within and among salmon populations of each species across the Chehalis Basin. Spring-run Chinook spawn in three primary areas within the Chehalis Basin, and the proposed dam project would significantly affect one of these three important spawning areas. The dam project would reduce salmon population abundances even further below 70% of historical abundance than the reductions predicted from climate change alone.

Moreover, the proposed dam would foreclose being able to restore the upper Chehalis River using modern restoration methods to rebuild the population segment produced there. A recovery plan for Chehalis River spring Chinook would need to target that area for restoration. An Aquatic Species Restoration Plan (ASRP), developed as part of a major cooperative effort called the Chehalis Basin Strategy, has placed a high priority on restoration of the upper Chehalis River for multiple species, including spring Chinook salmon (ASRPSC 2019). It bears noting that the Chehalis Basin Strategy has conflicting proposed actions, one of which is the major new dam at RM 108 and the other for restoring ecological processes and functions to that area.

Downstream of the major spawning streams used by spring Chinook in the Chehalis Basin, the lower mainstem Chehalis River and adjoining estuary have undergone extensive modifications from land and water use activities. Areas associated with the lower most part of the river and inner Grays Harbor are heavily populated, industrialized, frequently dredged, and receive discharge from municipal sewage treatment plants and treated effluent from nearby mills – although effluent from mills has been significantly reduced. Modifications have been most substantial within the Grays

Harbor estuarine area within and adjacent to the Chehalis River mouth (Seiler 1989; Hiss and Knudsen 1993; Sandell et al. 2015). All of these areas provide vital feeding and transitional habitats for juvenile salmonids produced within the basin—including spring Chinook (Simenstad and Eggers 1981; Smith and Wenger 2001).

### c. Predation

Most of the mainstem Chehalis River, as well as the lower reaches of the Newaukum River, are inhabited by large numbers of native and non-native piscivores that are known to have or likely to have negative interactions with outmigrating juvenile Chinook salmon. These species include northern pikeminnow (native) and smallmouth, largemouth, and rock bass (all invasive). The abundance of the bass species is believed to be increasing in the Chehalis Basin. While all of these species are known to prey on juvenile Chinook, smallmouth bass are considered to be a significant threat to outmigrating juvenile Chinook (Tiffan et al. 2020).

### d. Hatchery-Related Effects

Several early-timed Chinook hatchery stocks were introduced into the Satsop sub-basin at least from the early 1950s into the 1970s, resulting in "summer Chinook" that spawn in the mainstem East Fork Satsop River, and occasionally Decker Creek, an East Fork tributary, from early September to mid-October (Kliem and Holden 2011). Large numbers of hatchery salmon and steelhead are released at various places in the Chehalis Basin each year. Species include fall Chinook, coho, and steelhead. On-station releases are made in the Humptulips, Wishkah, Satsop, and Skookumchuck rivers of different species. Fall Chinook juveniles are also released into the Wynoochee River (HSRG 2004). In addition, yearling coho and steelhead smolts are transported from their hatchery sites to the Newaukum and upper Chehalis River (Elk Creek) where they are released from acclimation sites (HSRG 2004). These releases potentially impact Chehalis River spring Chinook juveniles through competition and predation, besides possibly transmitting diseases (HSRG 2014).

### e. Changes in Population Structure

The population structure of the historical aggregate Chinook population in the Chehalis Basin (i.e., the spring and fall runs combined) was the result of the spatiotemporal distribution of the spawners that occurred, on average, over an extended period in the river basin. Changes in a species' historical spatiotemporal distribution of its spawners can alter population structure to such an extent to threaten the species viability (McElhany et al. 2000).

Migration and breeding timing are highly heritable traits in salmon (Carlson and Seamons 2008), which means they are also prone to selection and represent an evolutionary mechanism through which salmon populations can adapt to effects of climate change (Manhard et al. 2017). Selective pressures that alter or truncate timing of migration and breeding can therefore alter an affected population's resilience and productivity (Tillotson and Quinn 2018). For example, because spring and fall Chinook historically spawned in different locations or at different times in the watershed, further reductions or loss of the spring Chinook life history would create voids in the distribution of Chinook salmon in the Chehalis River. Reductions in spatial distributions may lead to heightened density dependence by compressing the spatial and temporal distribution of spawners, which increases competition for food and space amongst young-of-the-year juveniles that have limited dispersal ability (Teichert et al. 2011; Finstad et al. 2013). In turn, this could contribute to depensation and further depletion of the population (Walters and Martell 2004; Atlas et al. 2015), resulting in an eventual extinction vortex (Primack 2008).

The changes reflected the relative proportions of spring- and fall-run spawners seen in Figure 4 (bottom) indicate that population structure is being altered in the river basin. Figure 6 also demonstrates that significant changes are occurring in spawning overlap in both space and time by the run types. Thompson et al. (2019b) and Gilbertson et al. (2021) documented that significant hybridization is occurring between the run-types in the Chehalis basin, giving evidence of changes in population structure.

#### f. Climate Change

Climate change is expected to adversely impact wild salmon populations in the Chehalis Basin beyond harmful effects that have already occurred (McConnaha et al. 2017; ASRPSC 2019). The populations most vulnerable to climate change in the basin are spring and summer Chinook (McConnaha et al. 2017; ASRPSC 2019). Without some form of major intervention, there is a high likelihood that Chehalis spring-run Chinook salmon will be extirpated by the end of the century, if not much sooner.

Mantua et al. (2011) describe expected effects of climate change on rivers and salmonid species on the Olympic Peninsula:

- Future environmental conditions related to stream temperature, streamflows, and other factors will diminish the quality and quantity of freshwater habitats for many Olympic Peninsula salmon populations unless they are able to quickly adapt to those changes;
- Significant increases in thermal stress will occur for adult salmon that over-summer in freshwater and spawn in late summer and early fall, such as spring Chinook;
- Reductions in streamflows in late summer and early fall will affect adult pre-spawning salmon that are waiting to spawn and will subsequently spawn, such as spring Chinook; and
- Predicted increases in the intensity and frequency of winter flooding will negatively impact egg-to-fry survival rates Chinook due to redd and egg scour.

### C. Quinault River Basin

The Quinault River originates in the high peaks of the interior mountains of the Olympic Peninsula. The low terrain downstream of Lake Quinault contrasts with the steep slopes and high relief of the areas around Lake Quinault and in the headwaters. The river basin comprises 434 square miles and is one of the major drainages on the Olympic Peninsula. The Quinault Indian Reservation encompasses roughly the lower half of the river basin, including all of Lake Quinault, a large natural lake in the middle of the basin through which the Quinault River flows. Yearly precipitation is high, averaging 146 inches at Lake Quinault. In the upper basin, much of this precipitation falls as snow, while most falls as rain downstream of the lake.

Most of the river basin lies within the Sitka spruce and silver fir vegetation zones, although the old-growth forests were mostly composed of the “big four” tree species: western redcedar, western hemlock, Sitka spruce, and Douglas fir (Storm et al. 1990). Some specimens of these species in the basin were among the largest in the world. The steep topography and shallow soils of the upper watershed generate both a quick hydrologic response and a high susceptibility to mass wasting events. In contrast, the relatively flat terrain and outwash silts and clays downstream of the lake result in a low susceptibility to mass wasting events and a slower hydrologic response. Because Lake Quinault traps all sediment coarser than silt, the river downstream of the lake is a product of the interactions between the floodplain and the surrounding coastal piedmont.

The diverse character of the historical river basin, including the presence of the large lake in the middle of the basin, made the river highly productive for many salmon species, including spring Chinook (Brown 1982; Storm et al. 1990; QIN 2008). Spring Chinook are an important salmon species in the basin and were always a significant species to the native Quinault people. Prior to the Quinault River Treaty of 1855, the Quinault Basin was claimed by the Quinault Tribe as its ancestral homeland and was used for subsistence fishing, hunting, and use of plants for food, medicine and tools. The Quinault Indian Nation was party to the signing of the treaty. Formal land ownership recognized by the U.S. government began with the treaty, which brought about the creation of the Quinault Indian Reservation.

The Quinault Basin was historically a forested landscape—and largely is today. Current land uses within the basin include timber harvest, fishing, and tourism. The major landowner is the Olympic National Park (ONP). The Quinault Indian Nation (QIN) owns 32% of the basin, comprising most of the area downstream of Lake Quinault (QIN and USFS 1999). The USFS manages 13% of the watershed, mostly upstream of Lake Quinault. Private landholdings comprise only 4% of the lands in the basin. Rayonier Timberlands Company is the largest private landholder (QIN and USFS 1999). Washington State lands managed by the Washington Department of Natural Resources (WDNR) encompass 0.1% of the drainage area. Present-day settlements are small and include the village of Taholah and the Amanda Park and Neilton communities near Lake Quinault. The most common recent human disturbance within the watershed has been timber harvest, including clearcutting, broadcast burning, and planting of Douglas fir.

Downstream of Lake Quinault, the land and water are primarily under the jurisdiction of the QIN. Upstream of the lake, most of the area is under federal management through the ONP and the USFS. It is especially noteworthy, however, that much of the river's floodplain between the lake and the confluence of the East and North forks was homesteaded by non-Indian settlers beginning in the late 1880s. As a result of the extensive land clearing within the floodplain, associated with on-going efforts to control the river's path, the upper river underwent significant alterations and became increasingly unstable (QIN 2008). These events are believed to have triggered a deterioration in the riverine habitats in the upper river, resulting in significant declines in both the sockeye and spring Chinook populations (USBOR 2005; QIN 2008).

### 1. Population Trends and Status

Quinault spring Chinook are a wild and native population in the river, with no hatchery production occurring. The population is considered a distinct stock within the ESU on the basis of geographic isolation of the spawners from other north coastal populations (WDFW and WWTIT 1994).

The large majority of Quinault spring Chinook currently spawn upstream of Lake Quinault, especially in the East Fork (QIN 2008). Too little is known about the genetic composition of the population to separate the fish that spawn upstream and downstream of the lake into genetically distinct aggregations (WDFW and WWTIT 1994).

Over the past 100 years, the fishery managed by QIN has been concentrated in the very lower part of the river near the village of Taholah, just upstream from the ocean (Storm et al. 1990). Previously, Quinault people inhabited many smaller villages along the river, perhaps seasonally, and fished in many locations.

WDFW and WWTIT (1994) classified the spring Chinook population in the Quinault basin as "depressed" based on the escapement pattern at the time of that determination. Generally, however, the population trend at that time was considered to be stable. A more recent assessment of the population and its status was prepared by the Quinault Fisheries Division as part of developing a salmon habitat restoration plan for the upper Quinault River (QIN 2008).

Consistent harvest records from the tribal fishery are available beginning in 1952, and escapement estimates were made beginning in 1979 (Figure 7). (Note: The 1982 escapement was not monitored nor estimated.) Clear patterns and trends are difficult to discern from these data because escapement estimates are not available for the first half of the data set, and the harvest records are compiled from fisheries with variable regulations and levels of effort. However, useful information can still be gleaned from these records.

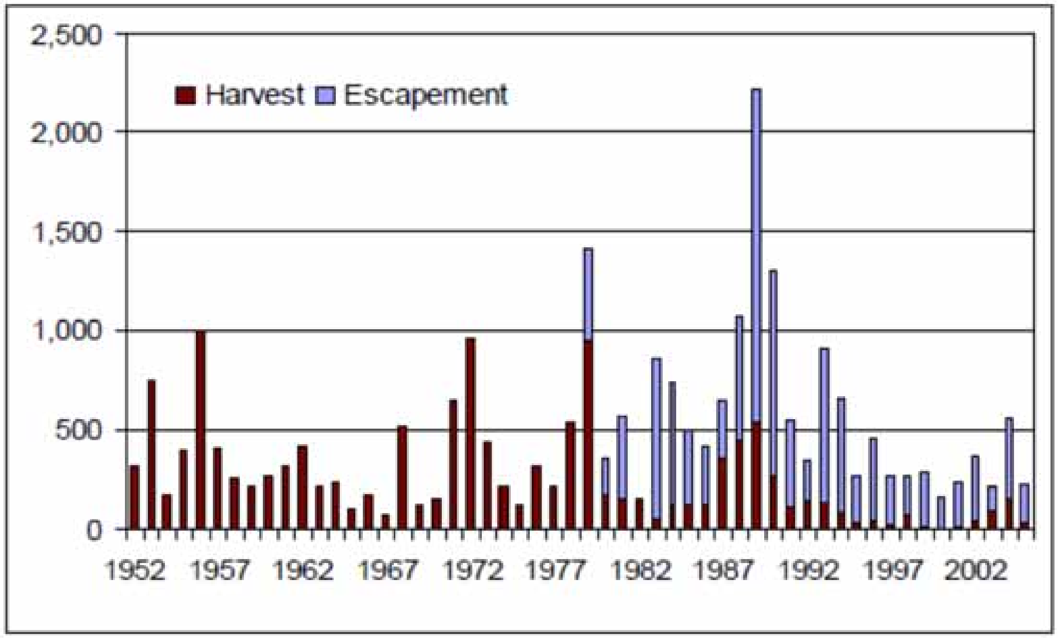


Figure 7. Estimated spring and summer Chinook gillnet commercial harvest in the Quinault tribal in-river fishery and spawning escapement in the upper Quinault River, 1952–2005. Figure taken from QIN (2008).

From 1952 to 1978, the tribal commercial fishery operated relatively consistently each year due to static fisheries regulations and management procedures throughout that period. Harvest of spring Chinook during that period was mostly influenced by abundance of the stock and the actual level of fishing effort (net days) exercised from April to August. The large majority of the fishing effort applied each year was during the sockeye fishery, using 4-5 inch mesh gillnet, which is not particularly efficient for catching Chinook salmon. The authors of the report concluded that the Chinook harvest during that period is useful as a measure of variation in annual Chinook abundance (QUIN 2008).

Annual total harvests ranged from 69 to 957 fish and averaged 350 fish from 1952 to 1978. There were occasionally relatively large harvests (1953, 1956, 1968, 1971, 1972, and 1978) likely due to exceptional survival for a single brood year production, but the general pattern was stable with no indication of increasing or decreasing trends.

Harvests after 1978 are not comparable to prior harvests because there were dramatic changes in the fisheries beginning in 1979, namely in the management policies for the sockeye fishery and other changes made for steelhead and early returning hatchery fall Chinook in August.

Although comparing run strength and stock status pre- and post-1979 is problematic, the addition of escapement estimates, beginning in 1979, allows more certainty for evaluating recent trends in spring Chinook abundance. Run sizes during 1979-2005 ranged from 165 to 2,215 fish. The sequence of large runs from 1988 through 1990 was from very unusual survival and production for the 1984 brood year. This was a general phenomenon seen in several spring chinook populations along the coast, including the nearby Queets and Hoh rivers. Since then there has been a general declining trend in run size.

The average run size since 1994 has been 298 fish, while the average from 1979 through 1994, excluding 1988 to 1990, was 659 fish. Escapements prior to 1995 (excluding 1988-1990) averaged 488 spawners, while escapements since then have averaged only 255. Although direct comparisons with run strengths prior to 1979 cannot be made, it is very informative that average run sizes for 1995-2005 are less than the average of harvest alone from 1952 through 1978; 298 vs. 350.

The salmon habitat restoration plan for the upper Quinault River presented by QIN (2008) made conclusions about the abundance, spawning habitat and spawning risk for spring-run Chinook:

- The abundance of spring Chinook by the 1950s must have already been significantly depleted from historical levels due to alterations of the upper river area, including extensive floodplain logging, land clearing, river channel modifications, unraveling of stable side channel complexes, and altered river channel processes in general. It is likely there had already been significant loss of habitat capacity and spring Chinook production by the 1950s. The extant data from 1952 through 2005 indicate the population was continuing to decline even though tribal harvests in the river fisheries had been reduced to very low levels later in the time period. The average harvest rate in the tribal commercial fishery was only 14% from 1996 to 2005. The apparent lack of response in the population to relatively robust escapements in 1987 to 1994 is troublesome. The low abundance and small escapements of the decade prior to the 2008 report, and the apparent lack of compensatory responses, suggest that the population may be vulnerable to depensatory processes in the environment and to further decline.

- Current suitable spawning locations for spring Chinook are limited to relatively few main channel and large tributary locations in the upper Quinault River, especially in the East Fork. The overall condition of habitats in the upper Quinault River is poor and getting worse. River channel spawning and early rearing habitats used by spring Chinook are expected to continue to deteriorate without intervention (USBOR 2005).

- Based on these assessments, the risk of further significant decline, and even virtual extinction, of the Quinault spring Chinook salmon was rated as moderate.

The statements given in QIN (2008) about the future population trend were accurate (see Figure 2, upper right). The number of spring Chinook spawners in the upper Quinault River continued to decline and in 2021 the number of spawners was estimated to be only 49 fish.

It is important to recognize that the restoration plan presented in QIN (2008) for the upper Quinault River is in the process of being implemented. It is a major, costly effort and can be expected to require a substantial period of years to be fully implemented.

### 2. Threats

The on-going threats to Quinault spring Chinook are significant—they can be categorized as continued fishery-related mortalities, freshwater habitat related factors, hatchery-related factors, and climate change effects.

### a. Harvest

Harvests directed at Quinault spring and summer Chinook within the river by both tribal and non-tribal sport fisheries ended several decades ago (QIN 2008). Incidental harvest of spring and summer Chinook occurs during tribal sockeye-directed fisheries in the lower river, when fishery openings occur (QIN 2008). The estimated average harvest rate by the tribal commercial fishery from 1996 to 2005 was 14% (QIN 2008) but it has likely been less in more recent years due to reductions in sockeye-directed fishery openings. It is likely that some fishing mortality occurs due to continued recreational fishery impacts, both upstream and downstream of Lake Quinault, including from catch-and-release mortality. Some poaching activities may also occur.

Significant harvest-related mortality likely continues to occur in ocean fisheries. Quinault spring and summer Chinook are very likely caught in commercial and recreational fisheries off the coasts of Washington, British Columbia, and Alaska, although the main impacts are expected to occur north of the Washington-BC border, as described in the section above on Chehalis Population Unit and Status. As explained, Quinault spring and summer Chinook can reasonably be assumed to be subjected to similar ocean harvest pressures seen in Figure 5, though likely at somewhat lower rates. Total brood year AEQ ERs on the Queets River exploitation rate indicator stock for fall Chinook has averaged about 60% over a period of decades and demonstrate no indication of decline over time (CTC 2023). Those ERs include terminal in-river harvest but the large majority of the harvest impacts occur in the ocean. The ocean fisheries are not managed in a manner to limit impacts on declining Washington coastal spring Chinook populations.

### b. Habitat Degradation

Logging and timber management has been the principal land use in the Quinault Basin for over 100 years (Storm et al. 1990). Logging of the lower basin (downstream of the lake) essentially eliminated the old growth forest over about a 60 period in the 20th century. Effects on tributaries downstream of the lake, as well as on the riparian condition of the mainstem river, were significant, changing water chemistry, sediment loads, stream temperatures, and wood loads (Lestelle and Blum 1989; Storm et al. 1990). Adverse effects on salmonid species that relied on tributary habitats were large, reducing wild coho run sizes returning to the river by about half (Lestelle and Blum 1989).

The effects of these logging operations that occurred downstream of Lake Quinault, however, did not extend to much extent to the Chinook salmon that spawned primarily upstream of the lake. There, Chinook spawn mainly in the mainstem river and in its side-channel networks (QIN 2008). The fry emerge in the spring from the spawning beds and begin a downstream migration to the ocean within the mainstem river, rearing as they go, which extends over a period of several months. Thus, they largely avoid the effects of the intensive forest management downstream of the lake that occur principally in the tributaries.

But the Chinook that spawn upstream of Lake Quinault, particularly the spring-run type, have been most vulnerable to legacy and on-going effects of floodplain land clearing, logging, and streambank protection measures that have occurred in the valley above the lake (Smith and Caldwell 2001; USBOR 2005; QIN 2008). Major alterations to the river channel network and its stability have resulted—and persist. Adverse effects to the sockeye and spring Chinook populations continue to the present time even though river restoration actions have begun. These effects are primarily due to bed scour during winter storms and associated disruptions to spawning areas.

It bears noting that effects of possible elevated water temperatures on spring Chinook in the mainstem Quinault River due to land use practices have not been documented and are uncertain. Even though the lower river has warm water temperatures, they appear to reflect the natural warming of water from Lake Quinault. Despite this, and coupled with low levels of poor shading, a "good" rating for water quality in the lower Quinault River mainstem has been given, based on Washington DOE standards (Smith and Caldwell 2001).

However, Spanjer et al. (2022) reported that under the current thermal regime, bioenergetics modeling predicts juvenile Chinook lose weight in the lower Quinault River; moreover, this loss of potential growth worsens by an average of 20–83% by 2080 with climate change projections.

### c. Hatchery-Related Effects

Currently, two hatcheries operate within the basin, where large numbers of hatchery salmon and steelhead are released each year. Species include fall Chinook, coho, and steelhead (HSRG 2004). On-station releases are made at the Quinault National Fish Hatchery, operated by the USFWS on Cook Creek in the lower basin, and at the Quinault Tribal Pen Rearing Facility and Hatchery located on Lake Quinault. These releases potentially impact Quinault spring Chinook juveniles through competition and predation, besides possibly transmitting diseases (HSRG 2014).

### d. Climate Change

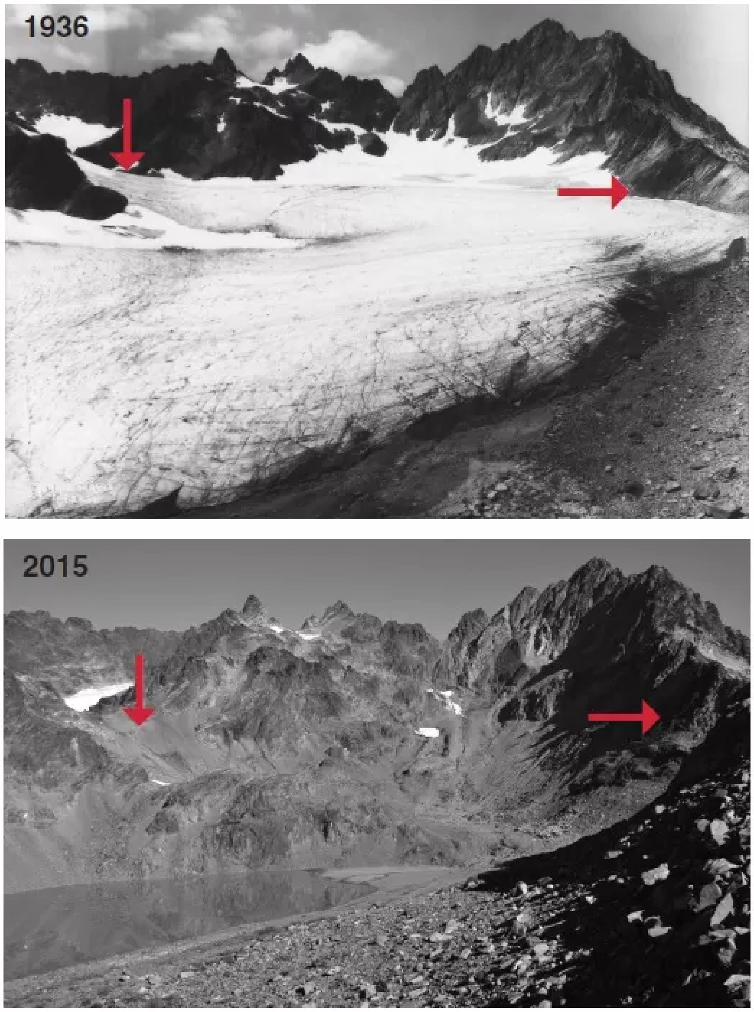
Climate-related changes are affecting flow levels, river channel characteristics, and water temperatures in the Quinault River system, and particularly upstream of Lake Quinault. There can be little doubt that these changes have already had significant adverse effects on the spring Chinook population in the Quinault Basin. Conditions are certain to worsen in the coming years (Halofsky et al. 2011) and significantly so (IPCC 2022).

The dramatic changes that have occurred to the Anderson Glacier, at the source of the East Fork, within 100 years are visual proof of the magnitude of changes that have occurred in the upper river (Figure 8). The massive glacier was located on the south face of Mount Anderson, an Olympic peak ascending to 7,330 ft. The glacier was once a constant source of cool water to the upper East Fork throughout the summer. Between 1927 and 2009, Anderson Glacier lost more than 90% of its surface area, and by 2011 it was gone (Ahearn 2015). The lack of glacial meltwater from the glacier resulted in the Quinault River reaching new record low flows (Ahearn 2015).

Glacial ice and perennial mountain snowfields in the Olympic Mountains are disappearing at an alarming rate; the same is happening in mountains throughout Washington State. The glaciers in the Olympic Mountains are expected to largely disappear by 2070 (Fountain et al. 2022). In 2015, the Olympic Mountains contained 255 glaciers and perennial snowfields totaling 25.34 ± 0.27 km2, half of the area in 1900, and about 0.75 ± 0.19 km3 of ice. Since 1980, glaciers shrank at a rate of −0.59 km2 per year during which time 35 glaciers and 16 perennial snowfields disappeared.

The loss of flow to the upper Quinault River from shrinking glaciers has had the opposite effect on sediment loading in the upper reaches of the river. As snowfields and glaciers have shrunk, massive volumes of sediment have been exposed to weathering and erosion along the upper slopes of the mountains (seen in Figure 8). This results in channel aggradation downstream, as sediment loads increase, causing instability of channels (Bakke 2009). The sediment loading from loss of mountain snowfields and glaciers is very likely a contributing factor to the instability of the upper Quinault River that has occurred over the past decades, as described in USBOR (2005) and QIN (2008).

Olympic National Park Glacier Repeat Photographs
Anderson Glacier



Arrows in identical locations illustrate the dramatic retreat/disappearance of this south-facing glacier.
1936 by Asahel Curtis; 2015 Byron Adams.

Figure 8. National Park Service comparison photographs show the dramatic retreat of Anderson Glacier

Mantua et al. (2011) describe expected effects of climate change on rivers and salmonid species in the Olympic National Park, including the upper Quinault River:

- Future environmental conditions related to stream temperature, streamflows, and other factors will diminish the quality and quantity of freshwater habitats for many Olympic Peninsula salmon populations unless they are able to quickly adapt to those changes;

- Significant increases in thermal stress will occur for adult salmon that migrate during summer and spawn in late summer and early fall, such as spring Chinook;

- Reductions in streamflows in late summer and early fall will affect adult pre-spawning salmon that are waiting to spawn and will subsequently spawn at that time, such as spring Chinook; and

- Predicted increases in the intensity and frequency of winter flooding will negatively impact egg-to-fry survival rates Chinook due to redd and egg scour.

## D. Queets River Basin

The Queets is the third largest river basin on the Washington coast; only the Chehalis and Quillayute river basins are larger. The basin encompasses 450 square miles. It is a diverse river system with highly varied tributary subbasins, which include Clearwater River, Salmon River, Sams River, Matheny Creek, and Tshletshy Creek. The Clearwater River is the largest tributary, with a subbasin approximately one-third of the entire Queets Basin. The main Queets River, roughly 53 miles long, originates on the southern slopes of Mount Olympus and on the north side of Mount Queets, fed by the Humes, Jeffers, and Queets glaciers.

Native Americans have inhabited the Queets Basin for thousands of years. The Queets River was the main watercourse for resource gathering, although the many tributary streams were also used for specific resource harvesting, such as salmon, eels, flora, and fauna. The Queets Tribe is part of the Quinault Indian Nation. The Queets Tribe was a party to the signing of the Quinault River Treaty of 1855. Subsequent to the treaty, the Quinault Indian Reservation was established in 1861. The reservation’s northern boundary encompasses the village of Queets, located on the Queets River just upstream of the Pacific Ocean.

The Queets Rain Forest, which blankets the river basin, is characteristic of the main Olympic Rain Forest along the west slopes of the Olympic Mountains. Annual precipitation averages nearly 150 inches. As in the other neighboring river basins on the coast, the forest grew trees that were among the largest in the world for its species, many of which still remain within Olympic National Park.

The Queets River system was historically productive for several species of salmon and steelhead. It was particularly productive for Chinook salmon—both spring-run and fall-run Chinook (Brown 1982).

In 1889, Euro-Americans began to homestead the Queets River valley for subsistence farming. These homesteads were also in the watersheds of tributary streams, including the Clearwater, Salmon, and Sams rivers, and Matheny Creek.

In 1897, portions of the Olympic Peninsula were placed in the Olympic Forest Reserve, which included parts of the Queets headwaters. These boundaries were later both reduced and added to and renamed the Olympic National Monument. In 1938, the Olympic National Park (ONP) was created, and additional land within the Queets Basin was added to the park.

Although acquisition of homesteaded properties in what is now called the Queets Corridor began during the 1930s, many farms were condemned in 1940 to create the corridor in 1953. Beginning in the 1940s, lands on the outside edge of the corridor were sold for timber harvest (James 2000).

Timber harvest began during the 1940s and 1950s in the Sams, Matheny, Salmon, and Clearwater sub-basins, with the peak of timber harvest taking place between 1960 and the mid-1980s. Generally, harvest activities started on the flatter valley floor areas and moved upstream into steeper terrain during the later portions of these decades. During this time period, increased road densities, stream crossings, and road construction on steep hillslopes amplified sediment inputs to many stream channels (Cederholm and Reid 1987; USFS 1995, 1997; QIN 2000). Most areas outside the ONP have been intensively logged and effects on aquatic habitats and salmonids have been significant (Cederholm and Reid 1987; Lestelle 2009).

Commercial timber harvest on U.S. Forest Service (USFS) lands in the Queets basin has been virtually non-existent since 1994 (Lasorsa 2002). Commercial harvest on private and DNR lands, primarily in the Clearwater subbasin, has continued although at a lower rate than during the 1980s (WDNR 1997).

The Olympic National Park includes 44 miles of the Queets River and 34 tributary streams (Phinney and Bucknell 1975). The Queets Basin upstream of the Sams River confluence (RM 23.5), including the Tshletshy Creek watershed, is part of Olympic National Park, with the lower five miles of the Sams River as the boundary between the Park and Olympic National Forest. The Queets Corridor is also under Park ownership and includes the mainstem Queets and its valley between RM 8 and RM 23.5 and the lower reaches of many tributary streams, including the Sams River (6,044 acres), Matheny Creek (387 acres), and the Salmon River (408 acres). Olympic National Park lands along the coastal strip include the lower mile of Kalaloch Creek. It is expected that timber harvest on these lands will be virtually non-existent.

The USFS manages 84% of the Matheny Creek watershed, 73% of the Sams River watershed, and 30% of the Salmon River watershed, as well as some acreage north of the Queets River near the town of Queets at RM 23. All of these watersheds have established Riparian Reserves, while lands outside of the Riparian Reserves are managed as Late Successional Reserves or Adaptive Management Areas (USFS 1995, 1997; Lasorsa 2002).

Washington DNR lands comprise 79% of the Clearwater sub-basin (T. Hartrich, QIN, unpublished data 2000). All Washington DNR lands in the Queets and Clearwater systems are managed as part of the Olympic Experimental Forest, which has a management objective of melding habitat conservation and timber production across the landscape, rather than separating each into designated areas. This management plan includes monitoring and research (WDNR 1997). The riparian conservation strategy calls for interior riparian buffer zones and exterior riparian wind buffer zones (WDNR 1997).

In the Clearwater sub-basin, privately owned lands comprise approximately 20% of the total acreage (T. Hartrich, Quinault Indian Nation, unpublished data 2000). Most of the privately owned lands are in the lower Clearwater sub-basin.

Lands in the Quinault Indian Reservation include the lower eight miles of the Queets River and the estuary, and 54% of the Salmon River drainage (South Fork, Middle Fork, and lower mainstem Salmon Rivers) (QIN 2000). These lands are managed under the Quinault Forest Plan for sustainable timber harvest, maintenance or enhancement of fish and wildlife habitat, consolidation of tribal lands, and enhancement of traditional and cultural values.

### 1. Population Trends and Status

Both spring and fall run Chinook occur naturally in the Queets River basin. No hatchery production occurs for spring Chinook; a small number of non-native spring Chinook were released into the river in the 1970s but there was no evidence of any appreciable adult return to the river.

The Queets fall Chinook population serves as an exploitation rate indicator stock for Washington north coastal fall Chinook. Starting with brood year 1977, juveniles produced each year from wild Queets fall Chinook and reared to release size in a hatchery have been annually coded wire tagged and released to monitor exploitation rates (HSRG 2004; CTC 2023). The number of juveniles produced in this manner is limited—the program is not intended to enhance fisheries. Returning hatchery fish are not used for brood stock.

Queets spring Chinook enter the river from March through August. The fall Chinook run enters during September through early November, with entry largely determined by timing of fall freshets.

Wild Queets spring Chinook are considered a distinct stock based on geographical isolation of the spawning populations from other Washington coastal populations (WDFW and WWTIT 1994). WDFW and WWTIT (1994) considered spring Chinook that spawn in the Clearwater River as a separate stock from those that spawn in the other areas of the Queets Basin, calling them summer Chinook. However, no data exists to define the population structure of the spring/summer aggregate population in the Queets system. Differences exist in spawning timing between spring and summer Chinook in different areas of the Queets Basin, as do spatial patterns of water temperature in the basin (Larry Lestelle, Biostream Environmental, personal communications).

Historical estimates of spring-run abundance information prior to the 1970s do not exist, aside from inferences that might be made from the older catch data dating to the early 1950s (see Figure 3).

An early account also exists made by Private Harry Fisher in September 1890 who became separated from a U.S. Army survey party exploring the interior of the Olympic Peninsula. Fisher was the first non-Indian to explore the river from its headwaters to the mouth (Brown 1982). He traveled down the Queets River at the time when spring Chinook salmon were actively spawning there. Camped along the river, he wrote in his journal for the night of September 25, “I might as well have selected a camp in Barnum’s Menagerie so far as sleep was concerned. Located near a shoal in the stream, great salmon threshed in the water all night long... At every few yards was to be seen the remains of a fish where cougar, coon, otter or eagle had made a meal.” This quote is taken from Private Harry Fisher’s journal published in Wood (1976). The account from Fisher supports a conclusion that the Queets River at the time of his journey supported large numbers of spring Chinook.

The Queets tribal fishery at the time of Fisher’s journey down the river occurred in many places along the river, from near the river mouth to the upper reaches where spring Chinook would have been abundant (Wood 1976). Fisher found old salmon drying racks used by the Indians over 30 miles upstream of the river mouth. His journey down the river ended a few miles upstream of the present-day Queets village, where he stayed with a Queets family and observed their fishing weir spanning the Queets River. Fisher’s journal notes suggest that he was amazed at the number of Chinook salmon in the river and the ease with which the Queets people caught them for their livelihood.

A salmon cannery was in operation at the mouth of the Queets River from 1912-1927, with catches ranging from 100 to 1,745 cases of Chinook, most likely both spring and fall run (Cobb 1930).

Some WDF records of monthly catch by the Queets tribal fishery date back to the 1930s but large gaps in the record exist (Wood 1984). More consistent records are available beginning in 1951, when daily records for many months and years are available—some data gaps exist (see Figure 3). More robust monitoring of the catch began in the mid-1970s when professional biological staff were hired by QIN (Storm et al. 1990).

Hook-and-line fishing by non-Indian people began with their arrival to the valley in the 1880s. By the mid-20th century, recreational fishing for spring Chinook had become popular in the Washington north coastal rivers and was well-established. Estimates of catch were always uncertain but were generally considered to be more reliable beginning in the 1970s, though the numbers are likely biased low.

By the 1970s, evidence was accumulating that the abundance of Queets spring Chinook was in decline, potentially sharply. PFMC and NOAA (1978) stated in the final Environmental Impact Statement for ocean fisheries commencing in 1978:

> “A few Washington coastal chinook runs appear to be in fairly good condition. Many runs are severely depressed owing to increased fishing pressure and environmental change. Certain races, such as Satsop early fall chinook and spring and summer runs on the Queets and Hoh Rivers are severely depleted.”

Bruce Brown, in writing his popular non-fiction work on Olympic Peninsula salmon (Brown 1982), visited the upper Queets River in September 1979 and surveyed spring Chinook spawner abundance with QIN staff; he described the decline of the run that was then increasingly evident. In 1994, WDFW and WWTIT (1994) described the status of the population as “depressed.”

By the turn of the century, the Queets tribal fishery for spring Chinook had been reduced to essentially nothing, with the exception of a few short fishery openings largely meant for ceremonial and subsistence purposes. The non-tribal recreational fishery in the river was closed.

Atlas et al. (2023) calculated the mean spring-run Chinook salmon spawner escapement in the Queets River basin from 1980 to 2019 was 677 fish, with a median decline of 2.45%/year; for the same time series mean escapement in the Clearwater tributary was 84 fish, with a median decline of 5.56%/year.

Figure 8 (top) depicts estimated run sizes of natural produced spring and fall Chinook salmon returning to the Queets Basin from 1978 to 2021. The years 1976 and 1977 are excluded from the figure because of high uncertainty in the spawning escapements in those years due to incomplete spawner surveys (Larry Lestelle, Biostream Environmental, personal communication).

It bears noting that the sequence of large runs from 1988 through 1990 was from very unusual survival and production for the 1984 brood year. This was a general phenomenon seen in several spring chinook populations along the coast, including in the adjacent Quinault and Hoh rivers. Despite this anomaly, Figure 8 depicts a statistically significant ($P<0.05$) declining trend from the late 1970s to 2021.

The Queets fall Chinook abundance estimates are plotted in Figure 8 (middle) along with spring Chinook abundance (upper). The small run of hatchery fall Chinook produced fish as part of the exploitation indicator stock program are excluded. The fall Chinook run sizes show little or no indication of a trend over the period.

In contrast, Figure 8 (bottom) shows that the percentage of the aggregate Chinook abundance comprised of spring Chinook returning to the Queets River for 1978 to 2021 is steadily declining. This demonstrates that the population structure of the aggregate population is changing over time.

It bears noting that the trend in Figure 8 (top) does not necessarily reflect the trend for ocean run sizes of Queets spring Chinook that might be seen if ocean run size data were available. Ocean run sizes estimated in adult equivalents (AEQ) are those that would be expected to return to the Queets Basin in the absence of ocean fisheries. No estimates exist for ocean AEQ run sizes of Queets spring Chinook, or for the other coastal populations for this run type, for the years shown in Figure 8.

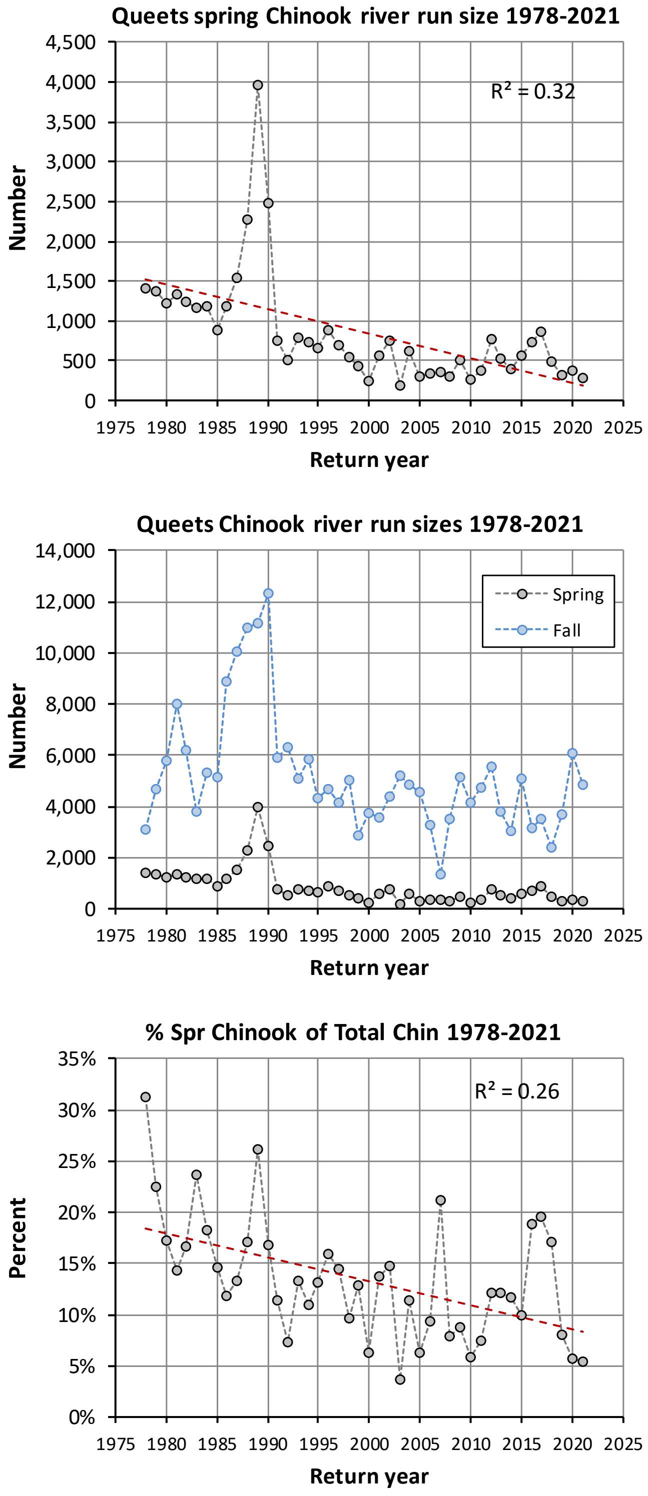


Figure 8. Top – Queets Basin estimated spring Chinook in-river run sizes, 1978-2021; middle – numbers of natural Chinook (spring and fall) returning to the Queets Basin; bottom – percentages of total natural aggregate Chinook run sizes comprised of spring Chinook salmon. Sources: PFMC database.

Similarly, no estimates exist of ocean exploitation rates (ERs) for Queets spring Chinook. It is reasonable to assume, however, that they track rates for Washington coastal fall Chinook populations to an extent due to their common ocean-type life histories and presumably similar northerly migrations along the continental shelf. Wood (1984) presented data, though limited, that showed similar ocean catch distributions for Hoh spring Chinook and Washington north coastal fall Chinook. The fall-run populations are far north migrating, being caught primarily in the coastal waters of British Columbia and southeast Alaska (Myers et al. 1998; Weitkamp 2010; CTC 2023). Queets spring Chinook can reasonably be assumed to be subjected to similar ocean harvest pressures seen in Figure 5, though at somewhat lower rates because in-river fishery harvest rates have been essentially eliminated on Queets spring Chinook.

In contrast to the pattern seen for Queets fall Chinook in Figure 8 (middle), the declining trend for Queets spring Chinook indicates that mortality from all sources combined exceeds the productive resilience of the spring-run type to sustain itself. Mortality factors include harvest and environmental effects, and potentially, effects of interbreeding among the run-types, though this has not been assessed as in the Chehalis River system.

### 2. Threats

The most evident threats to the sustainability of spring Chinook salmon produced in the Queets Basin are harvest-related effects outside the Queets Basin and habitat-related factors within the basin. Climate-change effects are manifested both within the basin through habitat factors and outside the basin through marine survival. Hybridization of the run-types is also likely threatening the sustainability of spring Chinook due to the relatively rapid change in population structure of the aggregate Chinook population. The cumulative effects of all threats combined pose a critical risk to the persistence of Queets spring Chinook salmon.

#### a. Harvest

Harvests directed at Queets spring Chinook within the river by both tribal and non-tribal sport fisheries ended more than 20 years ago with exception of occasional very limited openings for tribal ceremonial and subsistence purposes. Some limited fishing mortality may also continue to occur as catch-and-release fishing targeting other species, or as a result of poaching, either within ONP or outside of it.

Significant harvest-related mortality likely continues to occur in ocean fisheries. Queets spring Chinook are very likely caught in commercial and recreational fisheries off the coasts of Washington, British Columbia, and Alaska, although the main impacts are expected to occur north of the Washington-BC border, as described in sections above for the Chehalis and Quinault populations. As explained in those sections, Queets spring Chinook can reasonably be assumed to be subjected to similar ocean harvest pressures seen in Figure 5, though at somewhat lower rates because that figure includes impacts within the in-river fishery directed at Queets fall Chinook. The ocean fisheries are not managed in a manner to limit impacts on declining Washington coastal spring Chinook populations.

#### b. Habitat Degradation

Logging and timber management remains the principal land use in the Queets Basin outside the ONP on Washington State lands, private lands, and within the Quinault Indian Reservation. Washington State and private lands are primarily within the Clearwater subbasin; smaller tracts exist on the north side of the Queets River outside ONP and on lower Matheny Creek. Logging activities that generate fine sediment loads continue on these lands. Fine sediment from these activities is likely a major contributor to degraded habitats in these areas (Cederholm and Reid 1989; Lestelle 2009; WRIA 2011). Continued elevated sediment levels and related impacts likely persist to the present time in many areas where logging continues or where it was particularly severe in the past (Smith and Caldwell 2001; WRIA 2011).

The widescale clearcutting of all Queets Basin forests outside the ONP over the past century, which was greatly accelerated in the 1960-1980s, resulted in major changes to the riparian systems along most streams (WRIA 2011). The riparian corridor affects the aquatic system through influences on stream hydrology, sediment dynamics, biochemistry and nutrient cycling, temperature, physical habitat, and food web maintenance (Lestelle and Blum 1989; Naiman et al. 1998; Smith and Caldwell 2001; Berg et al. 2003; Dominguez 2006). The riparian system on these lands today is characterized by smaller trees, less diverse and smaller riparian corridors, reduced water storage, reduced micro-climate effects on streams, and reduced stability of stream systems (McHenry et al. 1998; Smith and Caldwell 2001; Dominguez 2006; Lestelle 2009; WRIA 2011). Invasive knotweeds are also damaging the integrity of riparian corridors.

The channel conditions and floodplains along the rivers and streams of the Queets Basin outside the ONP have been degraded as a result of the extensive clearcutting in the basin. The timber harvesting practices resulted in significant reductions of stable, large wood debris within the channels. Where wood loads are still high, it is usually in the form of smaller material that is more mobile and composed of species conducive to rotting. These conditions have resulted in changes to stream meso-habitats (pool-riffle composition) and a reduction in habitat quality (Lestelle and Cederholm 1984; Cederholm et al. 1997; McHenry et al. 1998; Lestelle 2009; Ruiz-Villanueva et al. 2016). These changes have likely reduced egg to fry survival of spring Chinook in the Clearwater subbasin, lower Matheny Creek, and Sams River, on USFS land) These effects likely continue to the present time.

There is excessive sedimentation in the more intensely logged areas, especially in the Clearwater subbasin (Cederholm et al. 1980; Klinger et al. 2008). Generally, water temperatures and side-channel floodplain habitat are in poor condition (Smith 2005; Klinger et al. 2008). Instream LWD, pool habitat, and riparian habitat are in fair condition (Smith 2005). Off-channel habitat is limited in the Clearwater, Sams, and Salmon Rivers and Matheny Creek (Klinger et al. 2008). On the Queets River, peak and low flows are intensifying (QINLE 2011).

The range of effects listed above occurring to altered riparian systems from landscape-scale logging can be expected to be exacerbated by climate change due to rising summer air temperatures and more intensive fall and winter precipitation events (Halofsky et al. 2011; Mantua et al. 2011). Increased peak flows expected as a result of climate change in fall and winter will worsen conditions affecting egg to fry survival (Halofsky et al. 2011; Mantua et al. 2011).

### c. Hatchery-Related Effects

Large numbers of hatchery salmon and steelhead are released at one location in the Queets Basin each year. Species include fall Chinook, coho, and steelhead. Fish are released from the Quinault Tribal Salmon River Hatchery, located on Salmon River (HSRG 2004). Salmon River enters the Queets River at RM 10.1. These releases potentially impact Queets spring Chinook juveniles through competition and predation, besides possibly transmitting diseases (HSRG 2014).

### d. Climate Change

Climate-related changes are affecting flow levels, river channel characteristics, and water temperatures in the Queets River system. As described for the other coastal river basins, there can be little doubt that these changes have already had significant adverse effects on the spring Chinook population in the Queets Basin. Conditions are certain to worsen in the coming years

(Halofsky et al. 2011; Mantua et al. 2011) and significantly so (IPCC 2022).

Glacial ice and perennial snowfields in the Olympic Mountains, including those at the headwaters of the Queets River, are disappearing at an alarming rate. As a result, low flows in late summer have been reduced over levels seen several decades ago, and water temperatures have likely increased. These changes can be assumed to affect survival of adult spring Chinook and reproductive success (Mantua et al. 2011).

Also, massive volumes of sediment have been exposed to weathering and erosion along the upper slopes of the mountains. This results in channel aggradation downstream, as sediment loads increase, causing instability of channels (Bakke 2009). These alterations over such a relatively short period of time have likely impacted egg to fry survival of spring Chinook in the upper Queets River. Expectations are that the glaciers in the Olympic Mountains will largely disappear by 2070 (Fountain et al. 2022).

At lower elevations and outside of the areas with glacial ice and snowfield influence, adverse effects of climate change can also be expected to reduce egg to fry survival, adult holding survival, and juvenile growth and survival (Mantua et al. 2011). These areas are in the Clearwater, Matheny, Sams, and Tshletshy subbasins.

### E. Hoh River Basin

The Hoh River basin, at 299 square miles in size, is the smallest of the Washington coastal river basins that supports spring Chinook. The mainstem river is a strongly glacially influenced river with headwaters located on the north face of Mount Olympus at an elevation of 7,980 ft. The main river, over 56 miles in length, ends at the terminus of Hoh Glacier, but it is fed by several glaciers on Mount Olympus, including Blue Glacier. Blue Glacier is the largest glacier in the Olympic Mountains.

Native Americans have inhabited the Hoh Basin for thousands of years. The Hoh Tribe, although considered to be a band of the Quileutes, is recognized as a separate tribe. The Hoh Tribe was a party to the signing of the Quinault River Treaty of 1855, in which their rights to maintain their fisheries in their usual and accustomed fishing places were recognized and preserved. The Hoh Indian Reservation, comprised of 443 acres adjacent to where the Hoh River enters the Pacific Ocean, was established by Executive Order in 1893. The Hoh village is located on the reservation. Hoh fishers conduct their river fisheries both on and off the reservation, as affirmed by the federal court case *U.S. v Washington* in 1974. The Hoh Tribe initiated its formal fisheries management program in January 1975 when it hired professional fisheries staff (Mattson and Klinge 1976). The program has been maintained since then.

The Hoh Rain Forest, which covers the river basin, is characteristic of the main Olympic Rain Forest along the west slopes of the Olympic Mountains. Annual precipitation averages 140 to 170 inches. As in the neighboring river basins on the coast, the historical forest grew trees that were among the largest in the world for its species; these still remain within the Olympic National Park.

Like its neighboring rivers, the Hoh River system was historically productive for several species of salmon and steelhead. It was particularly productive for Chinook salmon—both spring-run and fall-run Chinook. In the mid-20th century, the annual catch of spring Chinook by the Hoh Tribe was approximately half of the tribe’s total Chinook catch (Mattson and Klinge 1976). Of the five coastal river systems that supported spring Chinook historically, the in-river fishery harvest data indicate that the highest proportion of this run-type of the aggregate Chinook abundance in any river basin was in the Hoh Basin. This may be because the Hoh River has the largest amount of snowmelt runoff during the spring and summer months due to its origin on the north face of Mount Olympus (McHenry et al. 1996).

In the late 1800s, Euro-Americans began to homestead the lower Hoh River valley for subsistence farming. The homesteads were generally located in the lower third of the river basin.

The upper 65% of the basin, including the entire North Fork and the majority of the South Fork Hoh rivers, is protected within the ONP; that area is considered to be in pristine condition (McHenry et al. 1996; Smith 2000). The lower third of the basin consists of private land holdings and land owned and managed by Washington State through the Washington Department of Natural Resources (WDNR). These lands are principally managed for timber harvest.

### 1. Population Trends and Status

Both the spring and fall Chinook populations in the Hoh River are native and wild, although there have been several relatively small releases of hatchery propagated spring Chinook using native stock (WDFW and WWTIT 1994). Both populations are designated as separate stocks based on return timing and isolation from neighboring river systems (WDFW and WWTIT 1994).

The different life histories associated with each population enter freshwater and spawn at different times, and therefore, they also rely on slightly different locations for spawning within the river system, although there is some overlap during breeding (McHenry et al. 1996). Fall Chinook enter from September through November in a relatively mature state and spawn from late-October through January, mostly in the lower and middle portion of the mainstem Hoh River and in the lower reaches of several large tributaries (McHenry et al. 1996). Spring and summer Chinook are grouped by managers as one population. The adults enter from April through August, migrate quickly upstream, and tend to hold in deep pools until they spawn from late-August through September (McHenry et al. 1996). Most spawning occurs in the Olympic NP in the North Fork and South Fork Hoh rivers, almost exclusively in the mainstem rivers and associated side channels, and to a lesser degree, in a few smaller tributaries (McHenry et al. 1996). Spawning appears to be related to reductions in water temperature in late summer and early fall, resulting in slight spatial and temporal segregation with fish spawning up to a month earlier in the upper sections of the watershed compared to the lower-most spawning sites (WDFW and WWTIT 1994).

Historical estimates of spring Chinook in the Hoh River prior to the 1970s do not exist, aside from inferences that might be made from the older catch data that exist dating to the early 1950s (see Figure 3). But as described under the section for the Queets River in the account of Private Harry Fisher made in September 1890, his observations leave no doubt that the Hoh River, like the Queets, would have supported large numbers of spring Chinook historically.

Some WDFW records of monthly catch by the Hoh tribal fishery date back to the 1930s but large gaps in the record exist (Wood 1984). More reliable records are available beginning in the early 1950s, when daily records for many months and years are available (Wood 1984)—although some data gaps exist (see Figure 3). More robust monitoring of the catch began in the mid-1970s when professional biological staff were hired by the Hoh Tribe (Mattson and Klinge 1976).

Hook-and-line fishing by non-Indian people began with their arrival to the valley in the 1880s. By the mid-20th century, recreational fishing for spring Chinook had become popular in the Washington north coastal rivers and was well-established. Estimates of catch were always uncertain but were generally considered to be more reliable beginning in the 1970s, though the numbers are likely biased low.

By the 1970s, evidence was accumulating that the abundance of Hoh spring and summer Chinook was in decline. PFMC and NOAA (1978) stated in the final Environmental Impact Statement for ocean fisheries commencing in 1978:

> "A few Washington coastal chinook runs appear to be in fairly good condition. Many runs are severely depressed owing to increased fishing pressure and environmental change. Certain races, such as Satsop early fall chinook and spring and summer runs on the Queets and Hoh Rivers are severely depleted."

In contrast, other assessments suggested that the abundance of Hoh spring Chinook remained relatively stable into the 1990s. WDFW and WWTIT (1994) concluded that the population remained healthy and relatively productive compared to the escapement objectives. However, that report stated that the varying levels of impacts of prior interceptions in offshore fisheries obscure analysis of overall productivity trends. Huntington et al. (1994) evaluated populations of spring Chinook salmon across their range in the lower-48, and in that review, they identified Hoh spring Chinook as one of only five stocks classified as healthy. Similarly, a review by McHenry et al. (1996) suggested the population was relatively healthy, and a status review by NMFS in 1998 found the population to be abundant and productive enough that a listing under the ESA was not warranted (Myers et al. 1998). Atlas et al. (2023) calculated the mean spring-run Chinook salmon spawner escapement in the Hoh River from 1980 to 2019 was 1,356 fish, with a median decline of 0.51%/year.

Although Hoh fall Chinook salmon have remained abundant enough to continue to support in-river fisheries, trends in the in-river run size of Hoh spring Chinook have declined rapidly and dramatically since those reviews in the 1990s. For instance, run sizes from the early 1970s through the early 2000s ranged between approximately 1,500 to over 6,000 fish, but since that time, the population has been in sharp decline (Figure 9 top). As a result, the population has failed to meet its minimum escapement goal of 900 fish in 11 out of 22 years from 2000–2021, or 50% of the time (co-manager agreed-upon data, published at the PFMC website). Owing to the depleted run sizes, commercial and sport fisheries have been closed or greatly curtailed for most of the past decade. In fact, recent run sizes have been so small that managers have closed all sport fishing in the mainstem Hoh River during the summer so that anglers do not accidently encounter and potentially harm staging spring and summer Chinook. The declining status has greatly limited the Hoh Tribe's ability to fish for their most prized species, and further depletion could result in significant cultural and economic loss, both of which are critical to the persistence and success of the tribal people.

It bears noting that the sequence of large runs from 1988 through 1990 was from very unusual survival and production for the 1984 brood year. This was a general phenomenon seen in several spring chinook populations along the coast, including in the Quinault and Queets rivers. Despite this anomaly, Figure 9 depicts a statistically significant ($P<0.05$) declining trend from the late 1970s to 2021.

The Hoh fall Chinook abundance estimates are plotted in Figure 9 (middle) along with spring Chinook abundance (top). The fall Chinook run sizes show little or no indication of a trend over the period. In contrast, Figure 9 (bottom) shows that the percentage of the aggregate Chinook abundance returning to the Hoh River for 1976 to 2021 is steadily declining. This demonstrates that the population structure of the aggregate population is changing over time.

It also bears noting that the trend in Figure 9 (top) does not necessarily reflect the trend for ocean run sizes of Hoh spring Chinook that might be seen if ocean run size data were available. Ocean run sizes estimated in adult equivalents (AEQ) are those that would be expected to return to the

Hoh Basin in the absence of ocean fisheries. No estimates exist for ocean AEQ run sizes of Hoh spring Chinook, or for the other coastal populations for this run type, for the years shown in the figure.

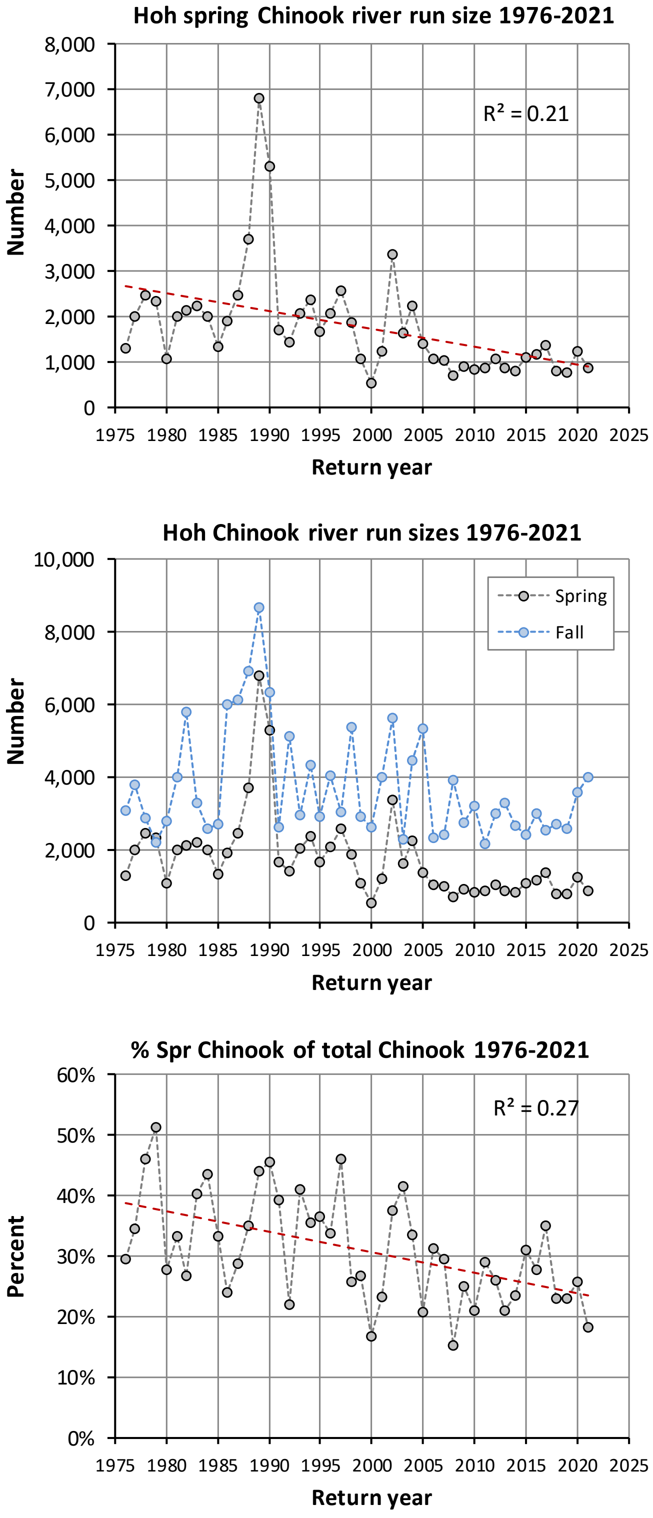


Figure 9. Top – Hoh Basin estimated spring Chinook in-river run sizes, 1976-2021; middle – numbers of natural Chinook (spring and fall) returning to the Hoh Basin; bottom – percentages of total natural aggregate Chinook run sizes comprised of spring Chinook salmon. Source: Pacific Fisheries Management Council

Similarly, no estimates exist of ocean exploitation rates (ERs) for Hoh spring Chinook. It is reasonable to assume, however, that they track rates for Washington coastal fall Chinook populations to an extent due to their common ocean-type life histories and presumably similar northerly migrations along the continental shelf. Wood (1984) presented data, though limited, that showed similar ocean catch distributions for Hoh spring Chinook and Washington north coastal fall Chinook. The fall-run populations are far north migrating, being caught primarily in the coastal waters of British Columbia and southeast Alaska (Myers et al. 1998; Weitkamp 2010; CTC 2023).

## 2. Threats

While a large proportion of the Hoh River basin is intact and protected within the boundaries of the Olympic NP, the significant decline in population size of spring Chinook underscores several factors that threaten the persistence of the population. Major threats influencing the status and trends of Hoh River spring Chinook include harvest, habitat degradation, influences of hatchery fish, changes in population structure, and climate change. The cumulative effects of all threats combined pose a critical risk to the population.

### a. Harvest

The effects of harvest on the status and trends of spring Chinook in the Hoh River have not been rigorously evaluated. However, there are concerns about exploitation rates, especially in the marine environment. Freshwater fisheries have been greatly curtailed over the past decade owing to declines in run size and more recently, tribal commercial and recreational sport fisheries have been significantly curtailed or closed entirely, underscoring the precipitous status of the population. Concerns about fishery impacts are so high that even catch and release sport fisheries have been closed for the entire summer to avoid inadvertent encounters with adult spring Chinook.

Despite the dramatic and well-intended conservation efforts by co-managers, there have not been similar changes in marine fisheries that occur throughout various locations and stages of the Chinook salmon's life cycle. Hoh River Chinook salmon, like other Washington coastal Chinook stocks, migrate far north in the ocean and contribute extensively to marine fisheries in the coastal waters of southeastern Alaska and British Columbia (Weitkamp 2010; Peterson et al. 2016).

Significant harvest-related mortality continues to occur in coastal marine fisheries. Hoh spring Chinook are very likely caught in commercial and recreational fisheries off the coasts of Washington, British Columbia, and Alaska, although the main impacts are expected to occur north of the Washington-BC border, as described in sections above for the other Washington spring Chinook populations. Hoh spring Chinook can reasonably be assumed to be subjected to similar ocean harvest pressures seen in Figure 5, though at somewhat lower rates because that figure includes impacts within the in-river fishery directed at Queets fall Chinook. As noted above, harvest of spring Chinook within the Hoh Basin has been greatly reduced, but the greatest level of harvest likely occurs in the coastal marine environment.

The ocean fisheries are not managed in a manner to limit impacts on declining Washington coastal spring Chinook populations. Given the strong declining trend and failure to meet escapement goals, it is impossible to see a future path to recovery unless the marine exploitation rate is greatly reduced. Additionally, and as important, is that millions of dollars have been invested in the Hoh River watershed to restore habitat and remove aquatic barriers in habitat outside the ONP (McMillan and Starr 2008). Returns on those investments will not begin to bear fruit and contribute to salmon recovery unless enough fish are allowed to return to the Hoh River and take advantage of the habitat. This will only be possible if ocean fishers also share the conservation burden and reduce their harvest rates to ensure a large and diverse population of adults return to the Hoh River each year.

### b. Habitat Degradation

Although the Hoh watershed has a substantial proportion of habitat protected within the ONP and adult salmon rely heavily on those upper river habitats for breeding, the vast majority of the lower Hoh River and its tributaries are unprotected. All adults and juveniles must also migrate through the mainstem Hoh River outside park lands, and juvenile Chinook extensively use mainstem river, mainstem side channels, and non-natal tributaries for several months as they grow in size before entering the ocean as a smolt (McMillan and Starr 2008). The combination of unprotected habitats, a legacy of poor land use practices outside the park and increasing effects from climate change are all factors that present threats to the persistence and genetic legacy of Hoh River spring Chinook salmon.

Forestry is the dominant land use outside the Olympic NP. Timber harvest in the Hoh River and other adjacent watersheds reached peak intensity from the 1950s through the 1980s, resulting in stream habitat degradation, including altered riparian zones, channel simplification, reduced amounts of instream wood, and increased mass wasting events and sediment delivery (Smith 2000; Martens et al. 2019). For example, research by the Hoh Tribe Natural Resources Department found that instream wood levels were lower and water temperatures higher in tributaries outside the park than for tributaries that had no history of logging (Hatten, Jim, Hoh Tribe Biologist, Unpublished Report).

Further, mass wasting events in the 1990s and 2000s, which were associated with logging of steep and unstable slopes, scoured many sidewall tributaries to bedrock and deposited large amounts of sediment in the mainstem Hoh and South Fork Hoh rivers (Smith 2000). In turn, the mainstem Hoh River channel has aggraded, resulting in fewer pools and more numerous smaller channels (Smith 2000; East et al. 2017). Staging adult Chinook rely heavily on deep pools and large wood for cover in the Hoh River (John McMillan, Trout unlimited, Unpublished data from snorkel surveys), so reductions in these types of habitat characteristics could lead to greater stress and competition. In addition, the mass-wasting events increased levels of fine sediment in the streambed, which likely has reduced intra-gravel flow and egg-to-fry survival (Smith 2000).

Lastly, the construction of extensive forestry road networks impeded fish migration at many stream crossings, blocking anadromous fish access to tributary habitats that juvenile Chinook salmon may rely on during the winter months (Smith 2000). Thus, stream habitat in the Hoh River has been, and continues to be, altered in ways that are known to reduce salmonid growth, survival, and reproductive success (Meehan 1991; Bisson et al. 1992). These impacts may have disproportionately affected spring Chinook that require complex mainstem habitats with deep pools and adequate cover to survive a two- to four-month over-summering period prior to spawning.

The Hoh River suffers from significant habitat degradation outside of the Olympic NP. Debris flows in the basin have been “common and devastating, resulting in scoured, incised channels with few spawning gravels and LWD” (Smith 2000). There are numerous areas with poor LWD and riparian conditions, passage blockages (in tributaries), degraded water quality, few floodplain complexes, and fog drip loss due to large conifer removal (Smith 2000). The Hoh River is also experiencing higher magnitude flood events and lower summer flows (Piety et al. 2004; East et al. 2017; NIFC

2020).

Changes to the physical habitat in the Hoh River watershed have been and will be further exacerbated by climate change effects. The wet, mild climate of the Hoh River is dominated by the influence of offshore marine air and is characterized by the highest precipitation levels in Washington State. Average annual precipitation ranges from about 90 inches (225 cm) near the Pacific Coast to 240 inches (600 cm) per year in the Olympic Mountains. Because of the rainfall, discharge fluctuations are highly dynamic and individual peak flows are greatest during winter months (e.g., November to February), while average monthly discharges are highest when snowmelt runoff occurs in June and July (East et al. 2017).

However, since 1980 there has been a marked reduction in the number and size of glaciers on the Olympic Peninsula (Malcomb and Wiles 2013; Riedel et al. 2015), the frequency of peak flow events in the Hoh has increased (East et al. 2017), and summer low flows have declined (USGS flow records). Less runoff associated with glacial retreat will reduce summer stream flows and increase water temperatures, both of which will likely lead to heightened stress for migrating adults and force them to rely on thermal refugia (Berman and Quinn 1991). A greater frequency of peak flow events, combined with mainstem channel widening (East et al. 2017), could have deleterious impacts – such as stream bed scour – on eggs and juveniles that rely heavily on the streambed for cover, especially during winter months (Collins et al. 2019). Hence, unless climate change patterns change dramatically, the effects will further alter stream flow and water temperature regimes, the combination of which will present greater challenges to successful reproduction by adults and growth and survival of juveniles.

### c. Influences of Hatchery Fish

Chinook salmon in the Hoh River are native and are not enhanced by hatchery releases (McHenry et al. 1996). However, each year hatchery spring Chinook (identified by their fin clip) migrate into the Hoh River and are captured by fishers and/or are observed spawning in the South Fork and North Fork Hoh Rivers (John McMillan, Unpublished data; Sam Brenkman, Riverscape survey). It has been presumed that the hatchery adults are strays from hatchery spring Chinook releases into the Sol Duc River, which is a tributary to the Quillayute River that enters the Pacific Ocean approximately 20 miles north of the Hoh River. Regardless of the source, hatchery Chinook are straying into Hoh River from April through June, some of which are likely interbreeding with the depressed population of wild Hoh River Chinook.

Hatchery salmon have lower fitness than wild salmon, even if derived from wild broodstock (e.g., Christie et al. 2014), and interbreeding may reduce the fitness and productivity of wild salmon populations (e.g., Chilcote et al. 2011). The genetic risks of interbreeding are likely exacerbated when the recipient population is small in size (e.g., HSRG 2014). The overall extent of hatchery straying and how many adults actually remain to breed in the Hoh River is unknown. Snorkel surveys conducted each September (2000-2007, 2009-2014, 2018-2019) in the lower 3-miles of the South Fork Hoh River, one of the preferred spring-run spawning locations, found approximately 0-22% of the staging adult spring Chinook in any given year were hatchery-origin (John McMillan, unpublished data). The surveys are not exhaustive, but it is clear some hatchery adults not only dip into the mouth of the Hoh River, but also migrate upstream where they stage and spawn near and/or with wild spring Chinook. Given the declines in wild fish, even fairly small numbers of hatchery strays represent a threat to the productivity and genetic legacy of wild Hoh River spring Chinook.

### d. Changes in Population Structure

The population structure of the historical aggregate Chinook population in the Hoh River (i.e., the spring, summer, and fall runs combined) was the result of the spatiotemporal distribution of the spawners that occurred, on average, over an extended period of time in the river basin. Changes in a species' historical spatiotemporal distribution of its spawners can alter population structure to such an extent to threaten the species viability (McElhany et al. 2000).

Migration and breeding timing are highly heritable traits in salmon (Carlson and Seamons 2008), which means they are also prone to selection and represent an evolutionary mechanism through which salmon populations can adapt to effects of climate change (Manhard et al. 2017). Selective pressures that alter or truncate timing of migration and breeding can therefore alter an affected populations resilience and productivity (Tillotson and Quinn 2018). For example, because spring and fall Chinook spawn in different locations in the watershed, further reductions or loss of the premature entering life history would create voids in the distribution of Chinook salmon in the Hoh River. Reductions in spatial distributions may lead to heightened density dependence by compressing the spatial and temporal distribution of spawners, which increases competition for food and space amongst young-of-the-year juveniles that have limited dispersal ability (Teichert et al. 2011; Finstad et al. 2013). In turn, this could contribute to depensation and further depletion of the population (Walters and Martell 2004; Atlas et al. 2015), resulting in an eventual extinction vortex (Primack 2008).

The changes reflected the relative proportions of spring- and fall-run spawners seen in Figure 9 (bottom) indicate that population structure is being altered in the river.

### e. Climate Change

Climate-related changes are affecting flow levels, river channel characteristics, and water temperatures in the Hoh River system. As described for the other coastal river basins, there can be little doubt that these changes have already had significant adverse effects on the spring Chinook population in the Hoh Basin. Conditions are certain to worsen in the coming years (Halofsky et al. 2011) and significantly so (IPCC 2022). The loss in glacial ice and perennial snowfields in the Olympic Mountains as described for the Quinault and Queets rivers are applicable, though perhaps less so at the present time due to the greater mass of glacial ice on the north face of Mount Olympus. But the future of the glaciers in the Olympics is dire; expectations are that the glaciers will largely disappear by 2070 (Fountain et al. 2022).

As noted in the section above for the Quinault River, increased sediment loading is likely occurring to the upper reaches of the rivers where Hoh spring Chinook primarily spawn. As the snowfields and glaciers have shrunk, massive volumes of sediment have been exposed to weathering and erosion along the upper slopes of the mountains (seen in Figure 10). This results in channel aggradation downstream, as sediment loads increase, causing instability of channels (Bakke 2009). This instability can be expected to decrease egg-to-fry survival within the spawning areas.

Mantua et al. (2011) describe expected effects of climate change on rivers and salmonid species in the Olympic National Park (see section for the Quinault River).

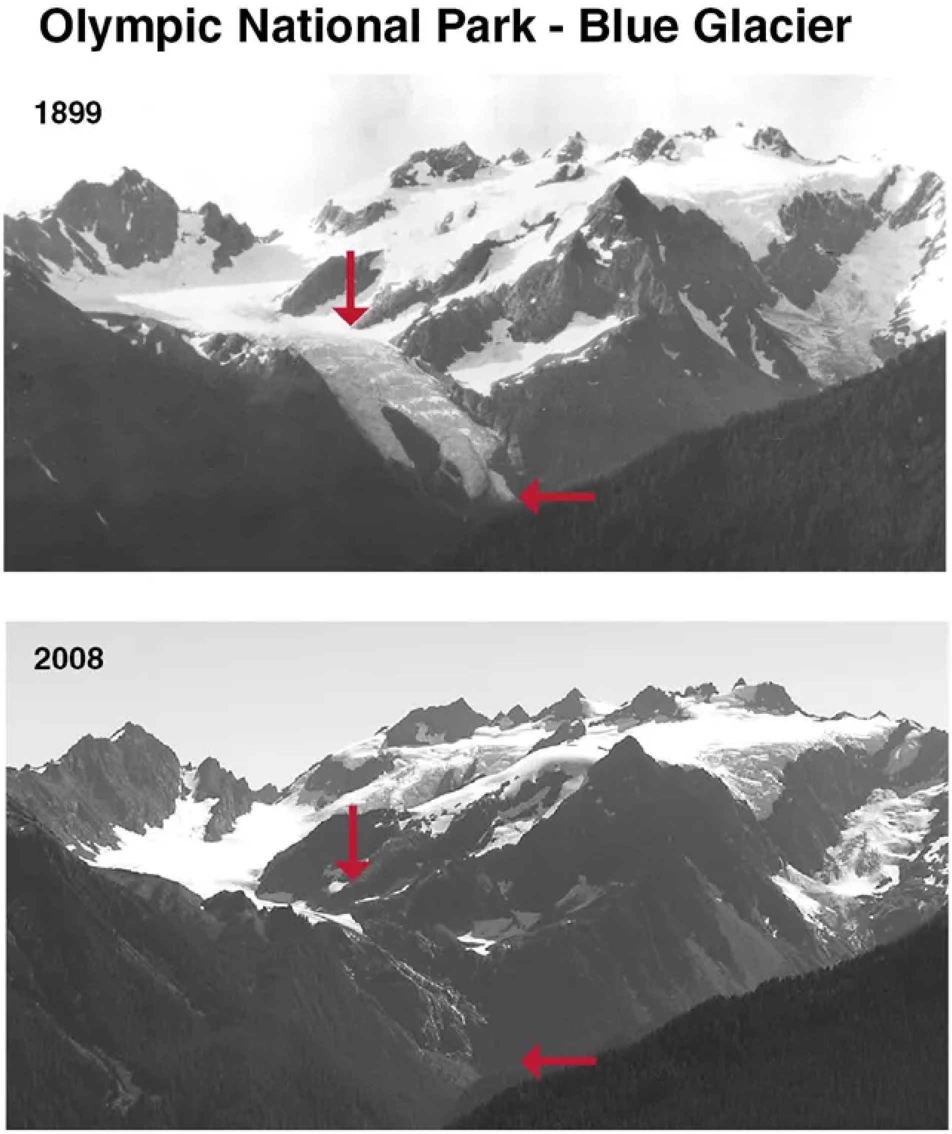


Figure 10. National Park Service comparison photographs show the dramatic retreat of Blue Glacier. Arrows in identical locations illustrate the dramatic retreat of this north-facing glacier. 1899: Olympic National Park archives. 2008: Jim Patterson, ONP

### F. Quillayute River Basin

The Quillayute is the second largest river basin on the Washington coast, only the Chehalis River Basin is larger. The basin encompasses 629 square miles (Phinney and Bucknell 1975). It is a diverse river basin with highly varied tributary subbasins. Four major rivers combine to form the Quillayute system. The Bogachiel, Calawah, Sol Duc and Dickey rivers drain the Northwest Olympic Peninsula westerly to the Pacific Ocean. The headwaters of these rivers generally originate in the Olympic National Park (ONP) from the Olympic Mountains, except the Dickey, which originates in lower elevations west of the Olympics. All of the rivers have extensive tributary systems with logging common outside the ONP boundaries (Hunter 2006). The Dickey has significant wetlands and is largely a low-velocity, low-gradient system. The other rivers originate in the Olympic highlands with relatively steep terrain which becomes more gradual some 15 miles from the Pacific Ocean (Hunter 2006). The Quillayute River has a very short mainstem of 5.5 river miles. At river mile (RM) 5.5 the Bogachiel and Sol Duc rivers combine to form the Quillayute

River. The Dickey River enters the Quillayute one mile from the Pacific Ocean and shares a common but limited estuary. The Calawah River joins the Bogachiel at RM 8.5 near the city of Forks, 20 miles from the mouth of the Quillayute River at La Push. The Sitkum River joins the South Fork Calawah at river mile 16.2.

Native Americans have inhabited the Quillayute Basin for thousands of years. The Quileute Tribe was party to the signing of the Quinault River Treaty of 1855, in which their rights to maintain their fisheries in their usual and accustomed fishing places were recognized and preserved. The Quileute Indian Reservation, comprising a land area of about one square mile at the mouth of the Quillayute River, was established by Presidential Executive Order in 1889. The village of La Push is located on the reservation. Quileute fishers conduct their river fisheries both on and off the reservation, as affirmed by the federal court case U.S. vs. Washington in 1974. The Quileute Tribe initiated its formal fisheries management program when it hired professional fisheries staff at about the time of that federal court decision. The program has been maintained since then.

### 1. Population Trends and Status

The Quillayute River system was historically highly productive for salmon and steelhead (Phinney and Bucknell 1975; Brown 1982). It is uncertain, however, how productive the basin was for spring Chinook. A WDFW salmon hatchery was built on the Sol Duc River tributary in 1970 and it was used to release non-native spring Chinook into the river in the mid-1970s. Since then, the Sol Duc River has supported a hatchery-origin stock of spring Chinook salmon, in addition to natural origin summer Chinook salmon. Fish considered to be summer Chinook are also present in low numbers in the Bogachiel and Calawah rivers (WDFW 1992). The hatchery stock of spring Chinook is derived from a combination of hatchery Chinook in the Cowlitz (Washington) and Umpqua Rivers (Oregon) (WDFW 1992). There is debate whether spring Chinook salmon were native to the Quillayute River watershed, and if so, whether they still exist (WDFW 1992 and 1994a). Tribal catch data from the 1950s suggests spring Chinook were harvested in fairly low, but consistent numbers, in the Quillayute prior to the introduction of the hatchery program, and that the spring run peaked by April 30 (WDFW 1952). Alternatively, it is possible that the fish entering the Quillayute were strays from nearby populations, such as the Hoh and Queets rivers.

Atlas et al. (2023) calculated the mean spawner escapement in the Quillayute River basin from 1980 to 2019 for fish considered to be summer-run Chinook salmon was 974 fish.

Unfortunately, genetic data have not been collected or analyzed to evaluate the presence of possible historical native spring Chinook salmon in the Quillayute Basin. Such information is critical to determining whether the unique race was present historically, but since no data exist to answer that question, one can only presume that native summer and fall Chinook are present in the basin.

### 2. Threats

The Sol Duc River tributary has excessive sedimentation from landslides and high road densities, poor LWD recruitment and riparian conditions, loss of wetland and off-channel habitat, low and warm summer streamflows, loss of fog drip, blockages in tributaries, and loss of cover and winter refuge habitat provided by debris jams (Smith 2000). The Bogachiel River tributary has poor riparian and LWD conditions, an aggraded mainstem that worsens as the river moves downstream, collapsing banks in the lower mainstem, fines from exposed clay layers, and warm summer water temperatures (Smith 2000). The Calawah River tributary experiences extensive landslides, high road densities, historic fire and subsequent salvage logging impacts, excessive sedimentation, poor levels of LWD, incised floodplains in the North Fork Calawah and South Fork

Calawah Rivers (as well as several tributaries), and low and warm summer streamflows (Smith 2000). The Dickey River tributary experiences sedimentation from roads and logging operations. The Dickey River has poor riparian habitat, extensive substrate embeddedness, low and warm summer flow, increased distribution of predators (e.g., northern pikeminnow), passage blockages, reduced fog drip due to the removal of old conifers, altered wetlands, decreasing LWD, and degraded channel and floodplain conditions in several tributaries (Smith 2000). Low streamflows and high water temperatures are believed to limit steelhead production in the river (Klinger et al. 2008).

## IV. Analysis of Threats Common to All Washington Coast Chinook Populations

### A. Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Habitat related alterations in Washington's coastal watersheds have affected the abundance, stability, and accessibility of mainstem gravel bars used for Chinook spawning and juvenile rearing. The deep, cold, over-summer holding pools required by adult spring Chinook have been filled in by sedimentation, decreasing habitat availability in the lower basins including the loss of mainstem islands and channel complexity. Water quality impairments occur in almost every coastal Washington watershed including temperature, sediment, turbidity, and in some cases toxins. Populations of spring Chinook spend portions of their lives in 303(d) listed streams throughout their range. Water quantity is also affected by municipal water withdrawal, agricultural, and industrial use. Estuarine habitats have been reduced in quantity by an average of 68% in many coastal basins and sea-level rise threatens to reduce available estuarine habitat in some areas, including eelgrass beds (Good 2000). Most of the upland impacts have been caused by historical and ongoing logging practices, while lower basins and estuaries have been impacted by agricultural practices, channelization, nitrification, and urbanization.

#### 1. Logging and Road Development

Roads alter streamflow, sediment loading, sediment transport and deposition, channel stability and shape, substrate composition, stream temperatures, water quality, and riparian conditions within a watershed (NMFS 2011). Roads contribute more sediment to streams than any other land management activity (NMFS 2011). Serious degradation of fish habitat can result from poorly planned, designed, constructed or maintained roads (NMFS 2011). Roads also affect water quality through applied road chemicals and toxic spills (NMFS 2011). Roads are correlated with increased landslides, debris flows and other mass movements (NMFS 2011). Road/stream crossings can be a major source of sediment (NMFS 2011). Plugged culverts and fill slope failures are frequent and often lead to catastrophic increases in stream channel sediment (NMFS 2011). Poorly designed culverts also can create a barrier to up and downstream movement of fish (NMFS 2011). Construction of roads adjacent to stream channels often precipitates riprapping of stream banks (NMFS 2011). In Washington Coast watersheds, historical and ongoing timber harvest and road building have reduced stream shade, increased fine sediment levels, reduced levels of instream large wood, and altered watershed hydrology (NMFS 2011).

Effects of Logging and Forest Land Use on Summer and Early Fall Streamflow

Perry and Jones (2017, following Jones and Post 2004) concluded, after an extensive study of long-term flow records in experimental watersheds in the Pacific Northwest, that an initial 10 to 15-year period of increased stream base flows (late spring, summer and early fall) after logging is closely followed by a period in which stream flows are reduced to about half of their pre-logging state for a period lasting from 15 through at least 50-years post-logging. Baseflow depletions of roughly 50% were observed in all study watersheds in which less than half of their area remained in mature and old growth forest, or conversely, in which greater than half of catchment area was logged. The hydrologic basis for this flow depletion appears to be increased evapotranspiration in second-growth forests—that is, greatly reduced water use efficiency—and possibly increased physical evaporation (from soil, or from condensation on the outside of foliage, etc.) in second-growth compared to mature and old growth conifer forests. The ultimate time frame for return to the higher stream base flow conditions observed before logging remains unknown. It could be 60 years, or it could be 120 years, or more—if the recovering forests are left to grow that long.

The research results of Perry and Jones (2017) and Jones and Post (2004) are derived from a set of relatively small experimental watersheds having perennial flows. However, most streamflow in larger-order streams where spring Chinook salmon occur derives from surface water contributed by small tributaries. Therefore, the flow depletion effects almost certainly scale up to produce substantial flow depletion in third or fourth-order streams where juvenile spring Chinook salmon hold, spawn, and rear. What is known about streamflow source areas and routing in Pacific Northwest watersheds gives us every reason to believe that most larger streams (except in rare cases of streams with unusual deep groundwater sources, lake outlets, or tidal influence) will directly reflect flow reductions seen in their tributaries. However, no research has been conducted to date of sufficient design to directly validate or invalidate flow depletion related to forest condition in higher-order, larger streams. It is important to recognize that Luce and Holden (2009) reported a widespread pattern of streamflow decline over 30 years of record at streamflow gauges across the Pacific Northwest (most of these longer-term records are from larger streams). Luce and Holden’s study was not designed to distinguish between effects of land use (or forest cover) and climate on the observed streamflow declines. Progressive logging that resulted in increased area of second growth forest cover could be either a primary driver or a contributor to such widely observed summer stream flow declines.

As Perry and Jones (2017) make clear, their results should be considered applicable to Douglas-fir dominated forests. Dominant conifer species in the forest type could play a significant role in the degree of streamflow depletion in second-growth thinned forests; ponderosa pine, for example, show much different, more conservative stomatal behavior and water utilization in the face of water stress then Douglas-fir.

Importantly, Perry and Jones (2017) studied some watersheds that experienced thinning of previously clear-cut tree plantations, and found that thinning did not alleviate water use or increase stream baseflows. This finding suggests that growth release of leave trees and the understory flush immediately following thinning increases the demand for soil water in proportion to the decrease associated with the removal of some stems. Shrubs often grow vigorously following canopy removal and soil disturbance caused by logging, including thinning, and some of these shrubs are capable of exploiting soil water sources at depth (Zwieniecki, and Newton 1996).

It is also important to note that the presence or relative size of riparian forest buffers appears to have little or no effect on observed flow depletions in the experimental watersheds. The experimental watershed record analyzed by Perry and Jones (2017) includes both clearcuts and patch cuts with uncut riparian areas, as well as partial cut riparian areas, but these variations recorded no difference in magnitude and duration of base flow depletion. The proportion of watershed area and of total soil water contained within riparian buffer areas is a small fraction of the total for the watershed. In view of these factors, there are both empirical and theoretical grounds to dismiss riparian forest buffers as ineffective in mitigating the whole-watershed effect of higher evapotranspirative water losses in upslope second-growth forests.

Critically complicating recovery or mitigation of streamflow depletion is that we still do not know the actual time frame for hydrologic recovery, or the stand age at which evapotranspiration water loss returns to the more conservative state characteristic of mature and old growth forest. Sustained low flow depletion occurred in all catchments that were more than 50 percent harvested within the 40-50-year time frame of observations (Perry and Jones 2017). All we know for certain is that hydrologic recovery has not occurred at 50 years; it might suddenly set in at 60 or 70 years, but it might not be consummated until stand ages reach 80, 100, or 150 years, or more. Because the flow deficit effect persists for at least 4-5 decades with no measured recovery, staggering logging within this time frame cannot generally be assumed effective to remediate streamflow depletion effects.

The time frame of more than 50 years for recovery of pre-logging baseflow conditions is critical because any forest harvest rotation age of 50 years or less, typical for private industrial forest lands in the Pacific Northwest, results in the vast portion of the landscape existing in permanently depleted base flow conditions. That is, while recently logged patches will generate higher base flows for ca.10-15 years post logging in localized areas, the majority of the landscape will remain perpetually in the second growth-dominated state that is associated with higher water loss and lower stream base flow. Because such a tiny fraction of the private industrial forest landscape remains in mature and old growth condition, stream low flow depletion is likely already widely, if not maximally expressed across these watersheds.

By contrast, on Federal Forest Service lands and within the Olympic National Park, there is sufficient mature and old growth forest remaining.

## Forest Land Use and Climate Change Co-Influence Streamflow Conditions

By increasing evapotranspiration, forest land use that produces extensive areas of second growth forest likely both reduces stream flow in summer and early autumn (prior to fall rainstorms) and increases summer water temperature by way of streamflow depletion. These effects move in the same direction as the projected effects of climate change. Luce and Holden (2009) demonstrated declining stream flows in recent decades in most longer-term streamflow records they examined from the Pacific Northwest. To date, it appears that no published research has examined the interactive causal influences on low flow depletion by logging versus forcing by climate change; we know that both factors can contribute to summer low flow declines. Therefore, it is abundantly clear that logging extensive areas in catchments supporting spring Chinook habitat is likely to aggravate and worsen the effects of climate change. Conversely, protecting or allowing restoration of mature forest cover over expansive areas of these catchments could benefit habitat conditions for spring Chinook and in part offset the expected harms from climate change.

Even under future climate warming scenarios, the thermal regime of some rivers is expected to remain with thermal tolerances of Chinook and other salmon species (Isaak et al. 2018). An expected general upstream shift of suitable habitat caused by summer warming, as projected by Isaak et al. (2018) and other forecasts, is likely to affect spring Chinook less than some other species, because spring Chinook already spawn and rear in habitats in more headwater habitats.

However, where physical barriers do not preclude fall Chinook migration, overlap in spawning and rearing habitats between fall and spring Chinook could increase in response to stream warming at lower elevations. Under these circumstances, increased redd superimposition and competitive or other ecological interactions among increasingly overlapping distributions of juveniles could adversely affect spring Chinook, and increase gene flow between fall and spring populations, jeopardizing the persistence of the early-migrating life history (Thompson et al. 2019). Overlap could be further increased should flow depletions render headwater tributaries less inhabitable or less accessible to spring Chinook. Further reduction or extended imposition of summer and early fall streamflow depletion as a result of logging and loss of diverse and mature forest cover can only further exacerbate these ecological stresses when Chinook salmon become more restricted to a narrower range of headwater habitats.

## Forest Practices and Roads

The mechanical processes involved in timber harvest and associated road construction alter many components and processes of aquatic ecosystems. Soil and site disturbance often results in increased rates of erosion and sedimentation, direct modification and destruction of aquatic and terrestrial habitats, changes in water quality and quantity, and disturbance of nutrient cycles within aquatic ecosystems (NMFS 2011). Physical changes from timber harvest affect runoff events, bank stability, sediment supply, large woody debris retention and temperature (NMFS 2011). Timber harvest can cause slope instability, erosion, and introduction of debris into stream channels; timber harvest practices such as roadcast burning and machine scarification and piling can increase sedimentation and thermal heating of streams and have the potential to damage habitat of anadromous fish (Chamberlin 1982; Everest and Harr 1982).

### 2. Dams, Water Diversions, and Migration Barriers

Dams

Large dams significantly reduce the amount of spawning and rearing habitat accessible to migrating Chinook salmon. Dams create physical barriers to fish passage, confound salmonid migration cues, and change downstream river flow and temperature regimes. Dams and the slack water reservoirs they create can seriously impede migration of salmonids, even where upstream passage is at least partially provided. Significant delays in the migration of spawning adults can occur while fish search for the opening to passage facilities. Dams can also pose passage problems for juvenile downstream migrants, with timely downstream movement stymied by the lack of current in reservoirs. Smaller dams and diversions for municipal, industrial, irrigation, livestock and rural uses can block or hinder upstream and downstream passage of migrating salmon and, if diversions are unscreened, can divert young salmon onto croplands along with irrigation water. The slack water impounded behind dams and diversions of all sizes can alter downstream water temperature and provide artificial habitats suitable for exotic and predatory gamefish. Unless dams are operated as run-of-the-river, they can modify downstream flow regimes, altering both seasonal and daily flow patterns to which spring Chinook are adapted (e.g. Thompson et al. 2019).

In the Chehalis River basin there are two large dams, on the Wynoochee and Skookumchuck Rivers. Both dams were built without fish passage and extirpated spring Chinook from important historical habitats. A new flood control dam proposal is under consideration for the upper Chehalis River that would extirpate and prevent recovery efforts of spring Chinook salmon from the upper Chehalis, one of three main spawning areas in the basin where spring Chinook historically thrived.

Water Diversions

Water diversion structures, as well as the slack water reservoirs they create, can seriously impede upstream passage of adults (and the later downstream migration of juveniles) both by creating physical barriers to passage and by confounding migration cues and exceeding biological tolerances through changes in river flow and temperature regimes.

Water in the Chehalis River basin has long been known to be over-appropriated, and water allocations in the basin exceed the actual stream flow in the river between April and October (Tetra Tech 2003). Low flows in late summer can also impede migration, besides adversely affecting survival of juvenile and migrating adult salmon. Water resources in the Chehalis Basin are insufficient to meet the needs of all existing water rights or to allow new rights to be issued to meet the requests of all prospective users. This is particularly true in the upper Chehalis Basin (WRIA 23) (Chehalis Basin Partnership 2004; NHC 2020).

Migration Barriers

WDFW noted multiple splash dam, mill dams, log jams and other impediments to upstream migration of salmon that had contributed to the decline of spring-run Chinook salmon in the

Chehalis Basin (Wendler and Deschamps 1955). In Washington Coast watersheds, fish passage has been blocked in many streams by improperly designed road culverts; and restricted in many estuary areas by tide gates (NMFS 2011).

### 3. Pollutants

In Washington Coast watersheds, stormwater and agricultural runoff reaching streams is often contaminated by hydrocarbons, fertilizers, pesticides, and other contaminants (NMFS 2011).

### 4. Channelization

Wetlands, marshes and braided channels in the lower reaches of the Chehalis River basin have been straightened, channelized, diked, drained, and deforested by agricultural and logging practices (ASRPSC 2019). Channelization decreases habitat complexity and productivity of juvenile chinook rearing areas, decreases summer flows and water quality, and increases water temperatures (Sedell and Froggatt 1984; Hulse et al. 2002; Lestelle et al. 2005).

## B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

### 1. Harvest in Ocean and Recreational Fisheries

Washington Coast spring Chinook are encountered in direct take commercial fisheries occurring off the coast of Washington, British Columbia and Alaska. These fisheries are conducted without ability to limit the impact to sensitive Washington coast spring Chinook populations. Commercial fisheries targeting other species also incidentally take Washington coast spring-run Chinook as bycatch. The management of ocean fisheries is conducted by the the U.S.–Canadian Pacific Salmon Commission and the Pacific Marine Fisheries Commission (PFMC), which is tasked with making pre-season forecasts, estimating total allowable catch, and setting fishing seasons in consultation with state and federal fisheries managers. Due to the mixed stock nature of these fisheries, it is extremely difficult to differentiate Washington coast spring Chinook with other Chinook stocks that co-inhabit marine waters. However, genetic mixture analysis research currently being conducted on these fisheries is improving assignment accuracy regarding population origin (Moran et al. 2018).

Co-occurring with commercial fisheries, marine recreational fisheries also incidentally intercept and directly take Washington coast spring Chinook. These marine sport fisheries occur throughout Washington, British Columbia, and Alaska and are primarily managed by state and provincial fish and wildlife agencies. Due to the mixed stock nature of these fisheries, it is extremely difficult to differentiate Washington coast spring Chinook with other Chinook stocks that co-inhabit marine waters. Washington coast spring Chinook are currently not factored into the development and management of recreational marine fishing seasons.

An essential problem is that no data are available to directly estimate harvest rates on any wild population of spring Chinook salmon in coastal Washington. Harvest rates estimated from tag recoveries from hatchery fish are assumed to be representative exploitation rates of wild populations, even though evidence suggests the greatly diminished wild populations remaining in most rivers are constrained by habitat conditions forcing relatively low productivity. Reisenbichler (1987) estimated, based on stock-recruit relations for Chinook salmon populations from the Pacific Coast, that total harvest should not exceed 60-70% to avoid overfishing and maintain stock resilience.

Unfortunately, the total harvest fraction still remains unknown for most wild spring Chinook stocks in Washington. Small population size and the lack of persistent recovery or sustained increase of these populations despite conservation measures in recent decades suggest they could be relatively low in productivity under current habitat conditions, and therefore vulnerable to overfishing.

It has been well-known for decades that crude regional estimates of salmon harvest cannot serve to ensure the conservation integrity of numerous small stocks that are harvested in mixed-stock ocean fisheries (e.g. Ricker 1973; Hillborn 1985). PFMC monitors ocean harvest of salmon and advises agencies on the regulation of ocean fisheries toward conservation objectives. Although PFMC (2018) has concluded that north-migrating Chinook salmon from the Oregon Coast were not overfished in recent years, their conclusions rely on a grossly aggregated regional analyses that lump small, less productive populations with larger, more productive populations (or rather, entirely ignore small stocks as they do not offer sufficient data to inform the statistics). The PFMC analysis also does not distinguish between spring Chinook and fall Chinook populations.

Recreational Chinook fisheries occur in freshwater or estuarine habitats in Washington coastal watersheds where hatchery augmentation is taking place, and on wild Chinook in the Chehalis, Queets, Quinault and Hoh basins in some years. Small populations of spring Chinook returning to smaller rivers are highly vulnerable to targeted fishing effort.

However, monitoring and assessment of freshwater harvest by the state is generally lax due to limited fiscal support, so while potentially high, freshwater harvest rates for most populations remain largely unknown. Spring Chinook are highly vulnerable to illegal fishing as well, and poaching mortality remains unquantified.

## C. Disease and Predation

It is unknown to what extent predation affects Washington coast spring Chinook, but WDFW does note avian, marine mammal, and non-native fishes as having the potential to negatively affect the abundance of both adult and juvenile salmonids. Non-native smallmouth bass (*Micropterus dolomieu*) are of particular concern in the Chehalis watershed.

The Washington coast has been a well-documented feeding ground for the Southern Resident Killer Whales, which feed on salmon.

Since the 1950s, California sea lions on the west coast have increased from about 10,000 to more than 300,000. Harbor seal populations along the Washington and Oregon coasts have grown from about 3,000 to 40,000. West Coast Steller sea lions numbered about 18,000 in 1979; today there are about 80,000. Seals and sea lions predate on Chinook salmon.

## D. Other Anthropogenic or Natural Factors

### 1. Hatcheries and Artificial Propagation

Large numbers of hatchery raised fall Chinook salmon are released annually throughout the Chehalis, Quinalt, and Queets river basins. Hatchery spring Chinook derived from a combination of hatchery Chinook in the Cowlitz (Washington) and Umpqua Rivers (Oregon) are released into the Sol Duc River, which is a tributary to the Quillayute River; and some of these fish migrate into the Hoh River. These hatchery fish releases potentially impact Washington Coast spring Chinook juveniles through competition and predation, besides possibly transmitting diseases (HSRG 2014). Hatchery salmon also have lower fitness than wild salmon, even if derived from wild broodstock (e.g., Christie et al. 2014), and interbreeding may reduce the fitness and productivity of wild salmon populations (e.g., Chilcote et al. 2011). The genetic risks of interbreeding are likely exacerbated when the recipient population is small in size (e.g., HSRG 2014).

### 2. Climate Change

The evidence of climate change is irrefutable. According to the IPCC, "[i]t is unequivocal that human influence has warmed the atmosphere, ocean and land" and that "[w]idespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred" (IPCC 2021). Each of the last four decades have been successively warmer than the last (IPCC 2021).

Under status quo emissions levels, average global temperatures are expected to rise 1.6° C above 1850-1900 levels between 2021 and 2041. Under the very high GHG emissions scenario (SSP5-8.5), global temperature will likely increase by 2°C between 2041 and 2060 (IPCC 2021). Climate change will affect the climate and hydrology of the Pacific Northwest. The region is projected to lose snowpack and glacier mass and incur frequent and extreme hydrological conditions (Mantua et al. 2010; Halofsky et al. 2011). Most models indicate that winters will be wetter and summers will be warmer and drier (Mote and Salathé 2010; Elsner et al. 2010; Kunkel et al. 2013). Summer droughts will be more frequent and severe (CIG 2009; Mantua et al. 2010; Halofsky et. al 2011).

The western Olympic Peninsula is anticipated to warm, although it may warm slightly less than other areas of the Pacific Northwest due to the moderating effect of the Pacific Ocean (Halofsky et al. 2011; Dalton et al. 2016). Annual precipitation is projected to increase during the winter and spring and decrease during the summer (Dalton et al 2016). Snowpack is projected to decline and streamflows are projected to increase in the winter and decrease in the summer (Dalton et al. 2016). The Olympic Peninsula is also expected to experience sea level rise, stronger and more frequent storms, increased erosion, warmer water temperatures, more low and high flow events, and increased glacial melt (Miller et al. 2013).

Climate change will also significantly alter the marine environment. Under the RCP8.5 scenario, models indicate that more multi-year warming events will occur in the northeast Pacific Ocean (marine heatwaves, MHW), which may cause profound effects on salmonid habitat (Joh and Di Lorenzo 2017; Oliver et al. 2019; Cheung and Frolicher 2020). According to Joh and Di Lorenzo (2017), "Widespread and extreme negative impacts on marine life and fisheries associated with the 2014-2015 marine heat wave are well documented. If the projected increases in the area, magnitude and frequency of extreme warm events are realized, and they are superimposed upon a systematic anthropogenic warming trend; this combination would likely cause profound negative impacts on marine life and fisheries all along the west coast of North America, particularly those in the Gulf of Alaska in the second half the 21st century."

These changes will impact Washington coast Chinook salmon, especially the spring-run component. Climate change will adversely modify freshwater salmonid habitat on the Olympic Peninsula. Because of their longer freshwater residency, spring-run Chinook are more sensitive to these freshwater habitat changes than other salmonids (Halofsky et al. 2011). Climate change is expected to cause widespread declines in the quantity and quality of habitat for Olympic Peninsula Chinook (Halofsky et al. 2011). It is unknown whether these fish will adapt quickly enough to these changes. Halfosky et al. (2011) warn that "It remains an open question whether present-day salmonid fish populations on the Olympic Peninsula can adapt (either through phenological, phenotypic, or evolutionary responses) at rates required to deal with the combination of anthropogenic climate change and other habitat and ecosystem changes that will come in the next century (Crozier et al. 2008).

In estuarine habitats, the main physical effects of climate change are predicted to be rising sea level and increasing water temperatures, which would lead to a reduction in intertidal wetland habitats, increasing thermal stress, increasing predation risk, and causing unpredictable changes in biological community composition (NMFS 2011). In marine habitats, there are a number of physical changes that would likely affect salmonids, including higher water temperature, intensified upwelling, delayed spring transition, intensified stratification, and increasing acidity in coastal waters (NMFS 2011). Of these, only intensified upwelling would be expected to benefit coastal-rearing salmon; all the other effects would likely be negative (NMFS 2011).

Throughout the life cycle of Washington coast salmonids, there are numerous potential effects of climate change (Stout et al. 2010; Wainwright and Weitkamp, in review). The main predicted effects in terrestrial and freshwater habitats include warmer, drier summers, reduced snowpack, lower summer flows, higher summer stream temperatures, and increased winter floods, which would affect salmonids by reducing available summer rearing habitat, increasing potential scour and egg loss in spawning habitat, increasing thermal stress, and increasing predation risk (NMFS 2011).

## Projected Climate and Hydrological Changes

### Air Temperature

The Pacific Northwest has not experienced the same magnitude of warming since the period between glacial and interglacial periods (Dalton et al. 2016). Between 1900 and 2014, the average air temperature in Washington rose by approximately 1.5°F (USFWS 2020; Mote and Salathe 2010). This warming trend will continue. According to the Climate Impacts Group (CIG 2009), "Regardless of the scenario, warming is projected to continue throughout the 21st century in the Pacific Northwest. For the 2050s (2041 to 2070) relative to 1950-1999, temperature is projected to rise +5.8°F (range: +3.1 to +8.5°F) for a high greenhouse gas scenario (RCP8.5). Much greater warming is possible after mid-century under the more aggressive scenarios (RCP 6.0 and 8.5)." Models using less aggressive emission scenarios also project increased warming over the course of the 21st Century. For example, Elsner et al. (2010) used data from the IPCC Fourth Assessment Report to project that air temperatures will increase 0.3 C per decade in the Pacific Northwest. However, even this lower rate of warming could produce "profound changes in the hydrology and environment of the Northwest" (Mote and Salathe 2010).

Modeling shows that summer air temperatures in the Pacific Northwest will rise significantly. For example, multi-model averages of the A1B scenario indicate that average June through August air temperatures will increase at the following rates over the century: 1.7° C (0.43° C to 3.4° C) by the 2020s; 2.7° C (1.3° C to 5.1° C) by the 2040s; and 4.7° C (2.7° C to 8.1° C) by the 2080s (Mantua et al. 2010). Multi-model averages of the B1 scenario project June through August temperature to increase as follows: 1.2° C (0.18° C to 2.4° C) by the 2020s; 1.8° C (0.2° C to 3.7° C) by the 2040s; and 2.9° C (1.3° C to 5.1° C) by the 2080s (Mantua et al. 2010). Air temperatures on the Olympic Peninsula are projected to increase (USFWS 2020). Under the business-as-usual emissions scenario, air temperatures in the Olympic National Forest are projected to increase by 2° F to 5° F (approximately 1° C to 2.5° C) between 2016 and 2045 relative to late 20th Century temperatures (USFWS 2020). Air temperatures in Olympic National Park are projected to increase by 2.93° F between 2016 and 2045 and by 5.85° F between 2046 to 2075 (LCD 2022).

### Glaciers and Snowpack

Climate change is melting the Olympic Peninsula's glaciers (USFWS 2020) and reducing snowpack. Between 1980 and 2015, glaciers on the Olympic Peninsula decreased by 34%

(Riedel et al. 2015). During that period, thirty-five glaciers and 16 perennial snowfields disappeared (Fountain et al. 2022), including the Anderson Glacier, which contributed to streamflow to the Quinault River (Dalton et al. 2016; NIFC 2020). Other glaciers that provide water to the Quinault, Queets, Hoh, and Bogachiel Rivers (McHenry et al. 1996) are receding at rates higher than previously recorded (NIFC 2020). Significant reductions of glaciers at the headwaters of the Quinault, Queets and Hoh Rivers has caused lower summer flows and an increase in sedimentation from glacial till, filling in deep holes and reducing holding habitat for spring Chinook. Between 1981 and 2015, the glaciers that feed into the Hoh River decreased by 40% (NIFC 2020). Under the RCP 8.5 scenario, Fountain et al. (2022) estimates that glaciers will largely disappear from the Olympic Peninsula by 2070. Climate change is expected to reduce late spring snowpack on the Olympic Peninsula (Halofsky et al. 2011). Parts of the Olympic National Forest historically maintained snowpack until April 1st (USFWS 2020). By mid-century, most spring snowpack will only exist at high elevations in Olympic National Park, which will also experience "dramatic reductions" in spring snowpack (Elsner et al. 2010; USFWS 2020).

### Precipitation

The majority of climate models project that spring and summer rain will decrease on the Olympic Peninsula, with up to a 24% decrease in summer rainfall (USFWS 2020). At least one model, however, shows slightly wetter summers (LCD 2022). The majority of climate models project that fall and winter rain will increase on the Olympic Peninsula (USFWS 2020). Precipitation during the months of December through February is likely to increase by 4.5% to 5% on average and depending on location (Halofksy et al. 2011). Across the Pacific Northwest, spring precipitation has already increased by about 2%-5% per decade over the past century, a trend that will likely continue (Abatzoglou et al. 2014). A multi-mean model using a high emissions scenario projects a 6.5% increase in spring precipitation by 2041-2070 (Dalton et al. 2016). The Pacific Northwest will also experience wetter storm events (Miller et al. 2013). Some models indicate that storms will be wetter and stronger on the Olympic Peninsula (Halofsky et al. 2011).

### Streamflow

Climate change is altering the hydrology of watersheds on the Olympic Peninsula. Winter peak flows are getting higher, and summer low flows are getting lower (NIFC 2020). These conditions are predicted to become worse in the coming decades. These changes are occurring throughout the Olympic Peninsula, including in the Quinault and Hoh rivers, and are likely to have significant effects on fall and spring Chinook. For example, the lower 9km of the NF Calawah River (tributary of Calawah River in the Quillayute River system) went completely dry in 2002 killing thousands of salmonids (McMillan et al. 2013). The Calawah River is a lower-elevation, rain-fed tributary and is susceptible to drought conditions (Smith 2000). Considering low summer flows are likely to become worse in the future (Wade et al. 2013), streams like the NF Calawah may become uninhabitable during the summer months. This also helps explain why the Calawah River has experienced a large change in summer low flows relative to other watersheds.

Olympic Peninsula spring-run Chinook have high exposure to extreme low flows (Wade et al. 2013). Lower flows will decrease habitat availability, elevate water temperatures, and induce thermal stress on salmonids (Crozier and Zabel 2006; Wade et al. 2013; Dalton et al. 2016; Ohlberger et al. 2018). Reduced summer and fall streamflows in rain-dominated basins may adversely affect spring-run Chinook migration (Holafsky et. al. 2011). For example, there will be less cold water and fewer holding pools for migrating Chinook, which may be stressful and lower their reproductive success (Dalton et al. 2016). Summer streamflows are showing a decreasing trend on many Olympic Peninsula Rivers, such as the Hoh River (NIFC 2020). Climate change will exacerbate these effects (NIFC 2020).

Summer streamflows will continue to decrease on the Olympic Peninsula (Mantua et al 2010; Wade et al. 2013; Beechie et al. 2013; Dalton et al. 2016). Using A1B and B1 warming scenarios, Mantua et al. (2010) found that annual summer low flows on the Olympic Peninsula will be approximately 5% to 45% lower by mid-century. According to Dalton et al. (2016), average summer flows are projected to decline by 30% across the Quillayute, Hoh, Queets, and Quinault River basins. Summer flows in headwater areas will likely become more ephemeral or stop during the summer months, and the duration of low flow periods will increase significantly in all but the most rain-dominant basins, such as the Hoh and Queets River basins (Halofsky et al. 2011). Increased winter flooding may exacerbate summer low flow conditions by increasing porous sediment deposits (Halofsky et al. 2011).

Winter flooding is increasing and will continue to do so throughout the 21st century (NIFC 2020, Mantua et al. 2010). Peak flows are commonly at or above flood stage on the Bogachiel and Calawah Rivers (NIFC 2020). Average winter flows are projected to increase by at least 30% over the majority of stream reaches in the Quillayute, Hoh, Queets, and Quinault River basins (Dalton et al. 2016). Winter flow in stream reaches on the Quinault and Quillayute Rivers are projected to increase by 40% (Dalton et al. 2016). Late fall and early winter flooding is also projected to increase (Halofsky et al. 2011). It is important to note that these summer and winter streamflow projections are based on moderate (A1B) and low (B1) emission scenarios established by the IPCC. These scenarios project similar amounts of emissions through the mid-21st century as the A2 scenario, which is a high emissions scenario (Halofsky et al. 2011). The A2 scenario, however, projects higher emissions during the latter half of the century (Halofsky et al. 2011).

Olympic Peninsula Chinook have high exposure to increased winter streamflows (Wade et al. 2013). Average winter flows (January – April) are expected to increase by at least 30% by 2040 (Dalton et al. 2016). Average winter flows are projected to increase by 31-40% in the Hoh, Queets, and Quinault Rivers (Dalton et al. 2016). Increased winter flows could reduce the survival of developing eggs, embryos, and juveniles (Dalton et al. 2016) This is a higher risk in confined streams, which are more susceptible to scour (Halofsky et al. 2011). Peak flows could also reduce the availability of slow-water habitat for juveniles (Mantua et al. 2010; Halofsky et al. 2011), which may reduce parr-smolt survival rates (Halofsky et al. 2011). Spring-run spawners that have springtime egg incubation will likely be negatively impacted by earlier, higher spring peak flows and increased scour during those events. Increased runoff will also likely increase sedimentation in Chinook habitat (East et al. 2017). Increased winter precipitation will likely increase runoff and landslides from logging operations, which would increase sediment pollution in Olympic Peninsula rivers and streams (Klinger et al. 2008; Halofsky et al. 2011).

### Water Temperature

Water temperatures on the Olympic Peninsula are projected warm. Increasing stream temperatures pose higher risks to the quality and quantity of Chinook habitat. Using A1B and B1 emission scenarios, Mantua et al. (2010) projected that water temperatures will warm by 1° to 2° C. Based on models that use A1B and B1 scenarios, water temperatures likely to increase to levels that reduce growth and increase the risk of predation for salmonids (Dalton et al. 2016). For example, temperatures at or above 15° C can inhibit the smolt transformation process (Miller et al. 2013). Many stream reaches on the Olympic Peninsula already exceed 16° C and warmer spring stream temperatures could impede smolting and force Chinook populations to adapt to smolt during an earlier time. It is also possible that warmer temperatures could expand growing seasons and increase food web productivity (Halofsky et al. 2011), however this benefit could be offset by increased flooding, lower summer flows, and increase predation risks (Dalton et al. 2016). Additional food availability may be also offset by increased competition (Dalton et al. 2016).

### Projected Changes in the Marine Environment

Climate change is already altering nearshore and offshore habitat of Washington Coast salmonids (Klinger et al. 2008; Miller et al. 2013). These changes include warming sea surface temperatures and potential alterations in upwelling, hypoxia, and acidification (USFWS 2020). The scope and intensity of these impacts are uncertain (Miller et al. 2013). For example, it is possible that climate change could decrease upwelling, which would lower productivity (Klinger et al. 2008). It could also increase upwelling, although warmer ocean temperatures could limit productivity benefits (Miller et al. 2013). These changes will negatively affect salmon survival rates (e.g., Kilduff et al. 2015).

#### Sea Surface Temperature

Sea surface temperatures are projected to increase in the Pacific Northwest (Mote and Salathe 2010; Miller et al. 2013; USFWS 2020). Mote and Salathe (2010) projected that ocean surface temperatures will increase by approximately 1.2° C by 2050 relative to the 1970-1999 average temperature. Other models project that surface temperatures may increase by 1.2° C to 3° C by mid to late century (USFWS 2020). These projected increases are substantially outside 20th century variability (Mote and Salathe 2010). Marine heatwaves such as the 2014-2015 “Blob” are also likely to reoccur more frequently (Oliver et al. 2019; USFWS 2020) as the ocean heat content increases (Cheung and Frölicher 2020; von Schuckmann et al. 2020).

#### Upwelling

Climate change may affect upwelling, although there is much uncertainty about this possibility. For example, models have produced mixed results on whether upwelling favorable winds will change (Miller et al. 2013). There is some evidence indicating that upwelling patterns may become shorter and more intense (USFWS 2020). Increasing surface temperatures may influence the timing and magnitude of upwelling as well (Miller et al. 2013).

#### Acidification

The Pacific Northwest is vulnerable to ocean acidification (Miller et al. 2013). Increased acidification threatens key species in the food web, including zooplankton, pteropods, crabs, and krill (Busch et al. 2013; Mathis et al. 2015; Dalton et al. 2016).

#### Effect of Changed Marine Conditions on Washington Coast Chinook

NMFS anticipates that climate change will continue to limit ocean productivity for salmonids (Ford 2022). “Historically, ocean conditions cycled between periods of high and low productivity. However, global climate change is likely to disrupt this pattern, in general, leading to a preponderance of low productivity years, with an unknown temporal distribution (Crozier et al. 2019). Recent (2015–19) ensemble ocean indicator rankings include four of the worst seven years in the past 20, meaning that an entire salmon or steelhead generation could have been subjected to poor ocean productivity conditions.” (Ford 2022). Warming will also cause ocean salmonid habitat to progressively decrease throughout the century (Abdul-Aziz et al. 2011). Summer marine habitat is anticipated to contract 8-10% by the 2020s, 15%-19% by the 2040s, and 24%-43 by the 2080s (Abdul-Aziz et al. 2011). Although some forage fish may benefit from climate change, forage fish abundance is likely to decrease (USFWS 2020), resulting in less prey for salmon.

### 3. Ocean Conditions

Ocean conditions in the Pacific Northwest exhibit patterns of recurring, decadal-scale variability (including the Pacific Decadal Oscillation and the El Nino Southern Oscillation), and correlations exist between these oceanic changes and salmon abundance in the Pacific Northwest (Stout et al. 2010). It is also generally accepted that for at least 2 decades, beginning about 1977, marine productivity conditions were unfavorable for the majority of salmon and steelhead populations in the Pacific Northwest, but this pattern broke in 1998, after which marine productivity has been quite variable (Stout et al. 2010). NMFS (2011) was concerned about how prolonged periods of poor marine survival caused by unfavorable ocean conditions may affect the population viability parameters of abundance, productivity, spatial structure, and diversity for Washington coast salmonids. Although salmon have persisted through many favorable-unfavorable ocean/climate cycles in the past, much of their freshwater habitat was in good condition, buffering the effects of ocean/climate variability on population abundance and productivity. It is uncertain how these populations will fare in periods of poor ocean survival when their freshwater, estuary, and nearshore marine habitats are degraded (Stout et al. 2010).

## F. Inadequacy of Existing Regulatory Mechanisms to Address Threats

### 1. International

Pacific Salmon Treaty

The Pacific Salmon Treaty is an international agreement and cooperative fishery management process between the governments of the United States and Canada. The Pacific Salmon Commission was formed to manage the implementation of the Pacific Salmon Treaty. In effect, the treaty allocates the harvest of spring Chinook originating on the Washington Coast in foreign and domestic fisheries, but without specific consideration of the condition of those individual populations, or consideration of impacts to the declining Washington coast spring-run Chinook population.

### 2. Federal

#### a. National Environmental Policy Act

The National Environmental Policy Act (NEPA) (42 U.S.C.4321-4370a) requires federal agencies, including the USFS and National Park Service, to consider the effects of management actions on the environment. The NEPA process requires these agencies to describe a proposed action, consider alternatives, identify and disclose potential environmental impacts of each alternative, and involve the public in the decision-making process. NEPA analysis does not, however, prohibit these agencies from choosing project alternatives that may adversely affect Washington coast spring Chinook salmon or their habitats. As a result, the NEPA process often results in the disclosure of impacts but affords little to no protections. Agencies must analyze the impacts of their actions on the species, but are not required to select alternatives that avoid harm to spring Chinook. The USFS is a federal land management agency that operates under NEPA, and that regularly approves timber sales, maintains and utilizes roads, and conducts other actions that harm Washington coast spring Chinook.

A good example is the NEPA review currently underway by the Washington Department of Ecology (2020) for a potential new dam on the mainstem Chehalis River at river mile 108. This project would inundate one of the three primary spring-run Chinook spawning areas in the basin and prevent restoration of spring-run populations and their habitat in the upper river. The project proposes a suite of mitigation, management and habitat enhancement plans, even though the impacts of the dam project on spring-run Chinook salmon simply cannot be mitigated.

The dam would be designed to hold back flows during periods when flows exceed a threshold level, intended to ameliorate flooding downstream. The temporary reservoir formed would inundate more than 6 miles of the upper mainstem river and the lower reaches of several major tributaries. The area of inundation would encompass major historical spring Chinook spawning grounds in the upper river (Phinney and Bucknell 1975; Weyerhaeuser 1994; Lestelle et al. 2019).

During major or greater floods, gated outlets at the bottom of the dam would close, and water would fill a temporary reservoir behind the dam. The facility would store up to 65,000 acre-feet of water in a temporary reservoir. After a flood, the gated outlets would open, and water from the temporary reservoir would slowly drain back into the river. When the gated outlets are partially closed, fish would be transported upstream using a trap and haul facility, which involves manually moving fish upstream. Under normal conditions, the gated outlets would stay open and the river would flow normally. Fish would be able to move upstream and downstream through the facility.

Per Section 404 of the Clean Water Act (CWA; 33 Code of Federal Regulations [CFR] 320-332), the applicant for the proposed dam must obtain Department of the Army authorization to construct the proposed project if it involves the discharge of dredged or fill material into waters of the United States. Waters of the United States generally include rivers, streams, lakes, marine waters, and wetlands. The U.S. Army Corps of Engineers (Corps) has jurisdiction over waters of the United States in the project area. The Corps will decide whether to issue, issue with conditions, or deny a permit for activities within the Corps' jurisdiction. On January 31, 2018, the Corps determined the proposed project may have significant individual and/or cumulative impacts to the environment. Therefore, an environmental impact statement (EIS) is being prepared in accordance with NEPA. Preparation of the Draft EIS and a future Final EIS will support the Corps' permit decision. A Draft EIS was issued on September 18, 2020 (ACOE 2020). The Final EIS is still pending, although the process has been delayed due to modifications that are being made to the precise location of the proposed dam.

Analysis of potential impacts of the proposed dam on salmonid resources in the Chehalis Basin for the NEPA EIS is being made using an adaptation of the Ecosystem Diagnosis and Treatment (EDT) Model (McConnaha et al. 2017; ACOE 2020). Modeling results for the Draft EIS showed that spring Chinook would be especially adversely impacted by the proposed action. Impacts were predicted to reduce the number of spring Chinook returning to the upper mainstem river by 80% during the 5-year construction period (ACOE 2020, Appendix K). By late century, without effects of climate change being factored into the analysis, the conclusion was that "Spring-run Chinook salmon were completely wiped out in this portion of the project area during 10- and 100-year flood flow years."

The modeling results were concisely summarized at page 251 of 374 of Appendix K of the draft NEPA EIS for the effects of the dam facility and operations (referred to as the FRE structure):

> "Overall, the EDT model predicts that the FRE structure would have significant negative impacts on all four modeled species in the upper watershed (Above Crim Creek), and especially on spring-run Chinook salmon. While at a basin-wide scale impacts are predicted to be minimal for most modeled species, it should be considered that the upper watershed Above Crim Creek is currently beneficial salmonid habitat that can provide a buffer against future potential degradation,

> including climate change effects that were not included in this NEPA analysis, in the watershed."

As noted immediately above, the NEPA analysis did not address all relevant factors; it did not account for the effects of climate change (e.g., intensification of rainfall events and increased water temperatures) on spring Chinook in the Chehalis Basin. Moreover, no consideration was given to the cumulative effects of the proposed action that would accrue associated with harvest exploitation that occurs on coastal spring Chinook in marine waters described earlier in this document. Also, it is important to note that the focus of the NEPA analysis was on changes in average abundance in the modeling—virtually no consideration was given to the other parameters that define population viability, namely, intrinsic productivity, spatial structure, and biological diversity (McElhany et al. 2000).

A decision to permit a new dam that would contribute to the extinction of imperiled spring Chinook would demonstrate the ineffectiveness of NEPA to protect salmon resources that should be listed under the ESA.

### b. Endangered Species Act

Washington coast spring-run Chinook salmon are not currently protected under the federal Endangered Species Act. The Act offers potential protections through federal Habitat Conservation Plans (HCP) which cover non-listed species, or co-occurrence with other listed species.

#### i. Habitat Conservation Plans

**Washington Forest Practices HCP**

The Washington State Forest Practices HCP (FPHCP) covers timber harvest and road construction and maintenance on 6.1 million acres of forest lands west of the crest of the Cascade Range, and applies to 456,230 acres of mostly private timberlands on the Olympic Peninsula, with about 3% being state or county lands. The plan covers all unlisted ESUs of Chinook salmon. Although the FPHCP includes habitat protections that benefit aquatic species, NMFS and USFWS noted that forestry activities could still potentially adversely affect aquatic habitat by increasing temperature pollution and sedimentation and decreasing large wood recruitment (NMFS and USFWS 2006). Additionally, legal questions have been raised regarding whether the HCP's Clean Water Act assurances violate Washington's antidegradation policy and undermine the TMDL program (Steifel 2013). Federal agencies, including NMFS, have also raised concerns about water temperature, riparian function, and Clean Water Act assurances. There are also ongoing issues with water typing classifications as well. Water typing is fundamental to effectively protect riparian buffers from forest practices, and it can be used in other management contexts such as fish population assessments and harvest management. The FPHCP riparian buffer width rules are based on a water type classification system intended to identify fish-habitat stream reaches. Inadequate water typing under the FPHCP has been allowing classification of non fish-habitat reaches, and thus lesser riparian buffers and stream protections, based on inadequate surveys.

**State Trust Lands HCP**

The Olympic Experimental State Forest (OESF) was designated in 1992 and covers approximately 270,000 acres of land (WDNR 2016). The OESF includes parcels of state-owned trust land interspersed with private, federal, and tribal lands. WDNR's goal is to manage the state trust lands to generate sustainable revenue for counties, universities, and other trust beneficiaries, while also maintaining ecological values (WNDR 2016). Nearly half of the forest is young, with trees ranging between 20 and 39 years of age (WDNR 2016). Several major rivers occur in the OESF, including the Hoh, Queets, Quillayute, and Clearwater rivers. WDNR does not manage streams in the OESF to meet desired future conditions for salmonids (WDNR 2016). Instead, it seeks to maintain or aid the restoration of riparian functions, water quantity, and water quality (WDNR 2016).

The Washington Department of Natural Resources (WDNR) manages state trust forestlands under the State Trust Lands Habitat Conservation Plan (the “DNR HCP”) (WDNR 1997). The OESF is one of nine planning units under the DNR HCP (WDNR 1997). The DNR HCP includes a Riparian Forest Restoration Strategy that aims to restore salmonid habitat (WDNR 1997). Under that strategy, riparian buffers differ in width based on particular stream needs and disturbance history (WDNR 2016). Generally, the average riparian buffers, which are measured horizontally from the outer edge of the 100-year floodplain, are 150 feet on type 1 and 2 streams and 100 feet on type 3 and 4 streams (WDRN 2016). These buffers are intended to minimize disturbance to unstable banks and adjacent hillslopes and maintain key biological and physical functions. This approach is not designed to achieve a desired future condition for salmonid habitat, but rather to “maintain or aid restoration of riparian functions important to salmonid habitat” (WNDR 2016). In addition to riparian buffers, the HCP includes other habitat protections, including road building requirements and wetland protections (WDNR 2016).

It is unclear whether the forest practices in OESF are significantly improving habitat for spring-run Chinook. For example, Pollock et al. (2004) found that “within the OESF, a majority of streams do not meet WDOE water quality standards for temperature, and that stream temperatures in harvested basins are often (but not always) higher and more variable than stream temperatures in unharvested basins” (Pollock et al. 2004). Additional study by Pollock et al. (2009) found that the impact of harvest activities could not be fully mitigated by riparian buffers alone. However, two studies by WDNR did not find similar water temperature exceedances within OESF (Martens et al. 2019; Devine et al. 2022).

Improved management standards have not increased large woody debris in streams in the OESF. Martens et al. (2019) found that large woody debris was either stable at reduced levels or declining, and that using passive restoration alone is unlikely to increase salmonid productivity. Marten et al. 2019) state “our results add to the current scientific literature that has found passive restoration of salmonid habitat in the Pacific Northwest is a slow process, which could take an additional 12–70 years for riparian forests and over 50 years for instream wood to accumulate.” The most recent monitoring report for the OESF also found that the majority of LWD is in decay, and that historic logging practices continue to interrupt the supply of new LWD to streams (Devine et al. 2022).

### ii. Co-Occurence with Other ESA Listed Species

Bull trout (*Salvelinus confluentus*) was listed under the Endangered Species Act as a threatened species in 1998. In 2005, the USFWS designated a series of waterbodies as critical habitat for coastal populations of bull trout. 70 Fed. Reg. 56212, 56304-56306 (Sept. 26, 2005). In 2010, the USFWS updated the designations for 32 critical habitat units, including the Olympic Peninsula Unit (75 Fed. Reg. 63898 (Oct. 18, 2010)). The USFWS designated 121 waterbodies as critical habitat in the Olympic Peninsula Unit, excluding certain geographic areas covered by the Washington State Forest Practices Plan (HCP) or covered by tribal plans. Id., at 63968-69369. Critical habitat for bull trout overlaps with some areas where Washington Coast spring-run Chinook occur, inlcuding portions of the Clearwater River, Hoh River, Quinault River, Queets River, Salmon River, South Fork Hoh River, and Tshletshy Creek. As a result, spring-run Chinook in these rivers and streams may benefit from critical habitat protection afforded to bull trout.

The marbled murrelet (*Brachyramphus marmoratus*) was listed under the Endangered Species Act as a threatened species in 1992. Critical habitat was designated for the marbled murrelet in 1996, and reconfirmed in 2016; this includes 1.2 million acres of federal lands and 429,000 acres of private lands in Washington state. Spring-run Chinook could benefit somewhat from protection of marbled murrelet nesting habitat consisting of stands of mature forest that can provide direct and indirect benefits to Chinook salmon streams, such as regulating stream temperature, providing streambank stability and preventing sedimentation. However, the overlap and potential benefits to Washington coast spring-run Chinook from listing and critical habitat protections for marbled murrelets are limited.

Though conservation initiatives on federal (Northwest Forest Plan) and nonfederal lands (Forest Practices Rules) have reduced the amount of habitat loss, authorized habitat loss continues under these and other initiatives such as federal Habitat Conservation Plans (Buchanan 2016). Killing, removal of habitat, and other “take“ of marbled murrelets is allowed under the Northwest Forest Plan, Washington State Forest Practices Rules, and Habitat Conservation Plans. As part of the Northwest Forest Plan (NWFP) monitoring, murrelet abundance at sea was estimated annually from 2000 to 2018 in inshore marine waters associated with the NWFP area (McIver et al. 2021). McIver et al. (2021) documented marbled murrelet declines from 2000 to 2018 for Washington state and its two conservation zones, finding strong evidence for a declining linear trend in Washington (-3.9 percent per year) and some evidence for a negative trend in Conservation Zone 2, the outer coast of Washington (-3.0 percent per year). This decrease in the outer coast of Washington represents an approximately 39 percent decline in murrelt abundance during a 17-year period  from 2001 to 2017. Given continued declines of marbled murrelets on the Washington Coast, presumed protections for murrelets cannot be relied upon as surrogate protection for spring-run Chinook or their habitat.

The northern spotted owl (*Strix occidentalis caurina*) was listed under the Endangered Species Act as a threatened species in 1990. Critical habitat was designated for the northern spotted owl in 1992, then revised in 2008, 2012 and 2021. This inlcuded 824,500 acres in the North Coast Olympics. Spring-run Chinook could benefit somewhat from protection of northern spotted owl nesting habitat consisting of stands of mature forest that can provide direct and indirect benefits to Chinook salmon streams, such as regulating stream temperature, providing streambank stability and preventing sedimentation. However, the overlap and potential benefits to Washington coast spring-run Chinook from listing and critical habitat protections for northern spotted owls are limited.

Two decades of range-wide monitoring (Davis et al. 2016) documented significant annual declines in spotted owl populations, and a 1.5% decrease of spotted owl nesting/roosting habitat on federal lands. The Washington Department of Fish and Wildlife reviewed the status of the Northern spotted owl in Washington in 2016 (Buchanan 2016), and found that the species continues to decline in the state by every metric used, and the population is becoming critically imperiled. Buchanan (2016) noted there is continued loss of murrelet habitat in Washington due to timber harvest. Though conservation initiatives on federal (Northwest Forest Plan) and nonfederal lands (Forest Practices Rules) have reduced the amount of habitat loss, authorized habitat loss continues under these and other initiatives such as federal Habitat Conservation Plans (Buchanan 2016). Killing, removal of habitat, and other “take“ of spotted owls is allowed under the Northwest Forest Plan, Washington State Forest Practices Rules, and Habitat Conservation Plans. Buchanan (2016) quantified the loss of murrelet habitat in Washington between 1993 and 2012: 24.3% loss on nonfederal lands and 0.7% loss on federal lands in the Olympic Peninsula, mostly due to timber harvest; 48.1% loss on nonfederal lands and 4.7% loss on federal lands in the

Western Lowlands, mostly due to timber harvest. Spotted owls had a -3.9% rate of population change during this period on the Olympic Peninsula (Buchanan 2016). Losses of murrelet habitat in Washington were mostly related to timber harvest, wildfire, range expansion and competitive advantage of the barred owl, and insect outbreaks, with timber harvest on non-federal lands comprising the greatest loss of habitat. Given that in just two decades one quarter of suitable spotted owl habitat on the Olympic Peninsula and half the suitable habitat in the Western Lowlands was lost, presumed protections for spotted owls cannot be relied upon as surrogate protection for spring-run Chinook or their habitat.

#### iii. Biological Opinion on Forest Management Activities

In 2020 the USFWS issued a biological opinion addressing Forest Management Activities on the Olympic National Forest (USFWS 2020). The biological opinion evaluates the potential effects of management actions on ESA-listed bull trout, northern spotted owl, and marbled murrelet. It requires certain conservation measures for projects that occur within bull trout core area watersheds or in designated critical habitat for bull trout. Several populations of spring-run Chinook occur in bull trout core area watersheds and critical habitat and therefore, may indirectly benefit from these conservation measures. These measures include the following: steps to prevent erosion and enable large wood recruitment; limits on commercial thinning and road maintenance activities; prohibitions on new culvert installations or culvert replacements; no-cut buffers restrictions; and road standards (USFWS 2020).

However, despite these conservation measures, the USFWS anticipates that adverse impacts will continue to occur in bull trout habitat (USFWS 2020). Spring-run Chinook that occur in the same areas as bull trout will likely incur some of these impacts as well. For example, new and temporary road construction, existing road reconstruction, road repairs, log hauling, road grading/blading, and drainage maintenance is anticipated to cause indirect adverse effects to bull trout. These effects include increased fine sedimentation, altered watershed hydrology, reduced water quality, and increased substrate embeddedness (USFWS 2020). The USFWS expects that the Queets and Quinault Core Areas will continue to be depressed by poor water quality (e.g., up to 408 tons of sediment per year in the Queets River) increased substrate embeddedness, and altered flow regimes caused by logging operations (USFWS 2020).

### c. National Forest Management Act and Northwest Forest Plan

Under the National Forest Management Act, the Forest Service is required to “maintain viable populations of existing native and desired nonnative vertebrate species” (36 C.F.R. §219.19).As with NEPA, this requirement does not prohibit the Forest Service from carrying out management actions and projects that harm species or their habitat, but merely states that “where appropriate, measures to mitigate adverse effects shall be prescribed” (36 C.F.R.§219.19(a)(1)). This clause does little to limit long term impacts to salmonid habitat in Washington coastal watersheds from agency management actions such as logging, road-building, mining and other activities. Washington coast spring Chinook salmon are not formally listed as a sensitive species by the Forest Service in Region 6, so they are not a priority species to protect or mitigate for habitat impacts.

In 1990, the USFS adopted a Land and Resource Management Plan (“LRMP") for the Olympic National Forest (USFS 1990). The USFS claimed that implementation of the plan would increase fish production potential by more than 10% by the end of first 10 years of implementation (USFS 1990). It also claimed that it would correspond with 1,200,000 additional anadromous smolts and that anadromous fish production would increase by 25% above then current levels due to decreased sedimentation and habitat enhancement projects (USFS 1990).

The 1994 Northwest Forest Plan (USDA and USDI 1994) was supposed to represent a coordinated ecosystem management strategy for federal lands administered by the Forest Service and Bureau of Land Management within the range of the Northern spotted owl, which overlaps significantly with the freshwater range of Chinook salmon. The Northwest Forest Plan established a system of federal reserves interspersed with matrix forestlands where timber harvest and other commodity production are given priority. Reserves were designed to provide large blocks of habitat for northern spotted owls and management on reserved lands generally attempted to protect species associated with older forests.

In 1998, the Olympic National Forest LRMP was amended to include management changes consistent with the Northwest Forest Plan. The NFP includes an Aquatic Conservation Strategy (ACS), which establishes measures intended to restore and maintain ecological processes of aquatic and riparian habitat (Thomas et al. 1993; Reeves et al. 2006). Though the owl reserves may not have provided extensive protection to species such as Chinook salmon whose life history traits occur at a different scale than the spotted owl, the ACS was explicitly supposed to protect native fish and their habitat. The ACS was supposed to provide safeguards for native fish by protecting their essential habitat needs through associated Standards and Guidelines that linked key watershed, riparian, hydrologic, physical, chemical and biological processes to types of land and water management actions and individual or groups of projects. The ACS included designation of riparian management zones, activity-specific management standards, watershed assessments, watershed restoration, and identification of key watersheds. Among other things, the ACS requires the USFS to “maintain and restore the sediment regime under which aquatic ecosystems evolved” (USDA 1994).

To date, the ACS has not maintained or restored the sediment regime under which Washington Coast Chinook evolved, and there is little evidence to suggest that the LRMP and the improvements made by the ACS have increased anadromous fish production by 25% or more over 1990 levels.

The ACS also established riparian reserves, which place primary emphasis on protecting fish habitat. The size of the buffers depends on whether the streams are designated as fish- or non-fish-bearing. Riparian buffers on fish-bearing streams are two site-potential tree heights (> 200 years old) or 300 ft, whichever is greater. Riparian buffers for non-fish bearing streams are one site-potential tree height or 100 ft, whichever is greater (Wilhere and Quinn 2018). The buffers are intended to help ensure that species meet certain viability standards (Wilhere and Quinn 2018). When developing the ACS, the USFS assumed that if a species has at least an 80% likelihood of a stable, well-distributed population over 100 years, it is viable (Wilhere and Quinn 2018).

The USFS is also guided by an Olympic National Forest Strategic Plan, which “integrates aquatics, wildlife, silviculture, and fire, helping to identify priority areas for management activities such as habitat restoration, road decommissioning, forest thinning, and fuel reduction treatments” (Halofsky et al. 2011). It also has a Road Management Strategy, which it developed, in part, to meet ACS standards (Halofsky et al. 2011). The road strategy sets priorities for road maintenance, upgrading, and decommissioning based on several factors, including aquatic risk and high-value watershed goals (Halofsky et al. 2011).

The NFP established the Aquatic and Riparian Ecosystem Monitoring Program to monitor whether implementation of the ACS is improving watershed conditions (Gaines et al. 2022). Unfortunately, the program has been hindered by insufficient funding and changes to monitoring protocols, which make it challenging to measure the impacts of the ACS on aquatic resources (Gaines et al. 2022).

### Roads

The ACS has not been effective in reducing road density or improving other road-related factors that affect salmonids (Frissell et al. 2014). According to Frissell et al. "[t]he magnitude of existing road impacts on watersheds and streams in the [NFP] may equal or exceed the effect of all other activities combined" (Frissell 2014).

Roads present major risks to fish and aquatic resources in the Olympic National Forest. In 2020, the USFWS stated that "forest roads in the Olympic National Forest have been a chronic source of sediments for decades" (USFWS 2020). Although the USFS has decommissioned 435 miles of roads in the Olympic National Forest since 1990 (Halofsky et al. 2011), hundreds of road miles still present significant risks to aquatic resources (USFS 2015). Fifty-one percent (1,032 miles) of all roads in the Olympic National Forest present high aquatic risks (USFS 2015). Thirty-three percent (651 miles) of the roads in the national forest are rated as presenting medium aquatic risks (USFS 2015). As a result, only 17% (338 miles) of roads in Olympic National Forest present low aquatic risk (USFS 2015). Nearly one-third of the Olympic National Forest's roads are proposed for decommissioning (Halofsky et al 2011). In addition to falling behind on road decommissioning, the Olympic National Forest has not received the funding necessary to bring all of the roads up to current standards (USFWS 2020). Additionally, some roads that have been previously maintained need additional work (USFWS 2020).

### Riparian Revegetation

Although there has been some revegetation in riparian corridors in the Olympic National Forest, many corridors continue to have few conifers because of historic logging practices (Halofsky et al. 2011). Reestablishing conifers in these corridors would help restore sources of large woody debris (Halofsky et al. 2011). However, these projects require costly, long-term commitments and, therefore, they have not been a high priority for forest managers (Halofsky et al. 2011). Additionally, treatments in riparian areas can disturb soils and decrease effectiveness in retaining sediment and nutrients (Frissell et al. 2014). Thinning in riparian areas can diminish summer flows because of increased water demand by regrowth of vegetation (Frissell et al. 2014).

## d. Olympic National Park

The forest and stream habitats in Olympic National Park have been protected for over 100 years, and it is in relatively pristine condition (Halofsky et al. 2011). In 1988, Congress designated 95 percent of the park as the Olympic Wilderness. The Olympic Wilderness, which was renamed the Daniel J. Evans Wilderness, covers 1,370 square-miles, including 48 miles on the Washington coastline. Portions of several Washington Coast spring-run Chinook salmon populations spawn and rear inside the Olympic National Park, which provides relatively pristine aquatic habitat conditions compared to areas outside of the park. The park's enabling legislation and the National Park Service Organic Act of 1916 (Organic Act) protect these resources. Specifically, the Organic Act requires the NPS "to conserve the scenery and the natural and historic objects and wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." 16 U.S.C. § 1. Historically, maintenance and repair of Olympic National Park roads that are adjacent to the Sol Duc, Hoh, Queets, and Quinault Rivers have caused major impacts on fish and aquatic life (Halofsky et al. 2011). Today, the National Park Service takes steps to reduce these impacts. For example, when feasible, the National Park Service relocates roads and other facilities from floodplains to other areas (Halofsky et al. 2011). It also limits construction of new facilities within floodplains to protect fish habitat (Halofsky et al. 2011).

However, spring-run Chinook habitat within the park is still impacted by legacy effects of previous logging activites and roads, as discussed in this petition. Despite improved forest practices, the effects of logging continue to impair salmonid habitat in the Olympic National Forest. Logging roads and associated channel crossings are still major issues for fish habitat quality (Halofsky et al. 2011). The USFWS describes the sediment input from roads in the Olympic National Forest as "chronic" (USFWS 2020). Although conifers have regenerated along some waterways, "many riparian corridors have few conifers to provide large wood to streams" (Halofksy et. al 2011). Spring-run Chinook within the park also face existential threats such as climate change, melting of glaciers, and reduced streamflows.

### e. Clean Water Act

The Clean Water Act (CWA) establishes the basic structure for regulating the discharge of pollutants into U.S. waters, and for regulating quality standards of U.S. surface waters. Under the CWA, the U.S. Environmental Protection Agency (EPA) implements pollution control programs and sets wastewater standards for industry and water quality standards for all contaminants in surface waters. The CWA also provides federal funding to restore habitat, clean up toxic pollutants and reduce run-off from farms and cities.

Under Section 404 of the CWA, discharge of pollutants into waters of the U.S. is prohibited absent a permit from the U.S. Army Corps of Engineers. Theoretically the CWA should provide some protection for stream and estuarine habitats used by spring-run Chinook. However, implementation of the CWA, and the Section 404 program in particular, has fallen far short of Congress's intent to protect water quality (e.g., *see* Morriss et al. 2001).

While the CWA may regulate pollutant discharge, it does not restrict all potential contaminants. Many pollution standards for industries are out of date, and new pollutant sources from pesticides and pharmaceuticals are constantly emerging. Also, much of the aging infrastructure for industries which attempted to address pollution during the early years of the CWA is in need of upgrades. The CWA does not address the leading cause of pollution today, in that it does not directly regulate "nonpoint" sources of pollution, such as logging and farming, leaving such efforts to states.

A limited number of logging-related activities are subject to the CWA. 40 C.F.R. § 1227.27. The silviculture rule does not apply to major sources of water pollution caused by logging operations. Among other activities, the rule exempts harvesting operations, surface drainage, and road construction and maintenance from which there is natural runoff. 40 C.F.R. at § 1227(b)(1). In 2013, the U.S. Supreme Court upheld the EPA's decision not to regulate stormwater runoff from logging roads. *Nw. Envtl. Def. Ctr. v. Decker*, 133 S. Ct 1326, 1338 (2013). The following year, Congress amended the CWA to effectively prohibit the EPA from requiring NPDES permits for discharges resulting from several silviculture-related activities, including surface drainage, road construction, and road maintenance. 33 U.S.C. § 1342(l). Therefore, the Clean Water Act fails to adequately protect Washington Coast spring-run Chinook salmon. Many river and stream miles occupied by Washington Coast spring-run Chinook salmon will experience water quality impacts caused by logging operations for the foreseeable future (McHenry et al. 1996). The synergistic effect of timber harvesting and heavier rainfall caused by climate change will impair water quality in rivers and streams where spring-run Chinook occur.

The CWA requires states to establish water quality standards to protect public health and welfare, enhance water quality, and serve the purposes of the Act. States follow a two-step process when setting water quality standards. First, they establish "designated uses" for individual waterbodies, such as the protection and propagation of fish. Next, they set allowable levels of pollutants to protect those uses. 40 C.F.R. §§ 131.10, 131.11. Washington has EPA-approved water quality standards; however, it is not meeting them in many rivers and streams where Washington Coast spring-run Chinook salmon occur (WDOE 2016; NIFWC 2020). The CWA requires states to list “impaired waters,” which include segments of waterbodies that do not meet water quality standards. The states must develop Total Maximum Daily Loads (TMDLs) that set the maximum amounts of pollutants that may enter impaired waters without violating water quality standards. The state may distribute those amounts or “loads” to various sources of point and nonpoint sources of pollution. In effect, a TMDL operates as a pollution budget for an impaired waterbody. Nonpoint source pollution drives water quality exceedances in the rivers and streams where Washington Coast spring-run Chinook salmon occur. Washington has not developed, and EPA has not approved, any TMDLs for any waterbodies where Washington Coast spring-run Chinook salmon occur.

### f. FERC Relicensing

The Federal Energy Regulatory Commission (FERC) authorizes the construction, operation and maintenance of non-federal hydropower projects and reconsiders licenses under the Federal Power Act (FPA) every 30 to 50 years. There is one FERC-licensed project in coastal Washington watersheds, the Wynoochee Dam in the Chehalis Basin.

Section 10(j) of the FPA allows federal wildlife agencies (U.S. Fish and Wildlife Service and National Marine Fisheries Service) to conduct environmental reviews and to make recommendations during relicensing that have the potential to add conditions and mitigations that can benefit native fish such as spring-run Chinook. The major issues addressed in comments by NMFS during FERC relicensing that relate to salmonids include protecting fish from being entrained into dam turbines or impinged on trash racks, providing upstream and downstream fish passage past dams, providing adequate base flows downstream from projects, reducing impoundment fluctuations, and providing flows in dewatered reaches.

Under the Fish and Wildlife Coordination Act (FWCA), FERC is supposed to give fish and wildlife resources "equal consideration" with hydropower and other purposes of water resource development, and incorporate the recommendations of federal and state fish and wildlife agencies. Measures suggested by NMFS to mitigate for project impacts to anadromous fish and to provide protection and enhancement - or an equivalent level of protection - must be accepted by FERC and incorporated into the license; unless FERC determines that the recommendations are inconsistent with the FPA or other applicable law. Section 18 of the FPA gives NMFS mandatory conditioning authority to prescribe upstream or downstream fish passage; these prescriptions must be incorporated into the license by FERC.

However, state and federal wildlife agency recommendations for fish passage and protection measures can be rejected by FERC if they make a determination that there is not substantial evidence of need – this has resulted in FERC refusing to require fish passage or deferring fish passage for projects which clearly block fish migration. FERC is the federal arbiter of conflicts between federal and state fishery agencies and hydropower developers, who often resist mitigation and compensation measures because they can be expensive and result in reduced power generation.

Historically, FERC has failed to adequately protect anadromous fish during licensing and relicensing; given inadequate consideration to fish and wildlife issues in its licensing decisions; been reluctant to impose license conditions for protection of fish and wildlife; and favored hydroelectric development over conservation of fish and wildlife (Bodi and Erdheim 1986). Bodi and Erdheim (1986) detailed FERC’s poor track record in complying with statutory standards for protecting anadromous fish, issuing exemptions for small hydropower projects and preliminary permits, deferring consideration of the effects of projects on fish and need for fishways until after it has approved projects, avoiding comprehensive planning for river basins, and inadequately consulting with fish and wildlife agencies. More recent FERC relicensing proceedings may have implemented more enlightened conservation measures in some cases (the biological adequacy of those measures often remains a matter of professional and public controversy, however), because FERC licenses extend for 30 to 50 years, threats inherent in past licensing actions often remain.

FERC relicensing often involves negotiations between NMFS, dam owners, states, other federal agencies such as the Army Corps of Engineers, and stakeholders, that can take very long – sometimes decades – to complete. Negotiated settlements that balance the needs of fish with other competing uses, such as power generation and recreation, may result in minimal gains for anadromous fish. The fact that FERC licenses come up for review only every 30 to 50 years means that for most rivers with FERC hydroelectric projects that impact anadromous fish, there will be no opportunity to address dam impacts through the FERC process in the near future.

The Wynoochee Dam in the Chehalis River basin was completed in 1972 for flood control, irrigation and industrial water storage; a powerhouse was added by Tacoma Power for hydroelectric energy in 1994. A FERC permit was issued for the dam in 1987, at which time there were no federally listed species or identified species of concern. The license does not expire until 2037. There is no NOAA Fisheries Biological Opinion, thus no federal agency recommended conditions and mitigations for the dam operation. Tacoma Power operates a fish collection facility two miles downstream from the dam, where a low barrier dam and a series of pools divert returning adult fish to a large holding pool where salmon and steelhead are separated from other species. Some salmonids are kept for brood-stock while the rest are loaded into a tank truck and hauled 5 miles upstream, past Wynoochee Lake, where they are released into the river to spawn. It is unclear how effective this manual upstream fish passage is, how many trucked fish successfully spawn, and whether their offspring can successfully migrate downstream past the dam. There are no FERC requirements for the dam to be operated to provide adeqaute downstream flows or water quality to ensure and enhance spawning and rearing success of salmonids downstream of the dam.

### 3. Washington State

The Washington State passed legislation for salmon recovery in 1998 (Revised Code of Washington Chapter 77.85), intended to make the state a proactive partner in the ESA recovery planning effort, and to fund habitat projects that assist in the recovery and enhancement of salmon stocks. The organizational framework to guide and implement salmon recovery through salmonid habitat restoration and protection involves three main participants, the Governor's Salmon Recovery Office, the Salmon Recovery Funding Board, and local Lead Entities. The Salmon Recovery Office in 1999 issued statewide salmon recovery strategy, Extinction is Not an Option, with the goal of restoring salmon, steelhead, and trout populations to "healthy and harvestable levels and improve habitat on which fish rely.” The Governor submits biennially to the Legislature a “State of the Salmon Report." The Salmon Recovery Funding Board makes grants and loans to local lead entities for salmon habitat projects and activities. It is important to note that the law specifically entrusts voluntary “lead entities” consisting of counties, cities, and tribal governments to develop the projects necessary for restoring and protecting fish habitat within the state’s 62 Water Resource Inventory Areas (WRIAs). In 2022, the Washington State Legislature funded a Salmon Recovery Funding Program, that encourages incentive programs for projects with landowners to retore areas critical in salmon habitat, otherwise known as riparian restoration projects.

Washington State government manages its responsibilities for fish, fish habitat—including water, and other natural resources primarily through the Washington Department of Fish and Wildlife (WDFW), Washington Department of Ecology (Ecology), and Washington Department of Natural Resources (WDNR). These departments are responsible to carry out the laws and policies of the state for managing, protecting, preserving, and perpetuating the state's fish, wildlife, and ecosystems, while also providing sustainable fish and wildlife recreational and commercial opportunities.

Washington State government also manages these resources cooperatively with the treaty tribes, as required through the federal court case *U.S. v Washington* in 1974. Each of the three treaty tribes on the Washington coast manages its fisheries-related resources with its own professional staffs. These staffs have frequent interactions with federal and state staffs who are also working to manage and protect those resources. The treaty tribes are also assisted in these efforts by the staff of the Northwest Indian Fisheries Commission (NWIFC). The NWIFC was created following the 1974 *U.S. v Washington* ruling. The role of the NWIFC is to assist member tribes in their roles as natural resources co-managers. The NWIFC provides direct services to the tribes in matters related to biometrical analysis, fish health, and salmon management. It bears noting that while the Chehalis Tribe is not a party to the Quinault River Treaty, it is a federally recognized tribe that is engaged in the management of fisheries-related resources in the Chehalis Basin. The tribe has a professional staff for this purpose.

Despite the extensive efforts of these state and tribal management entities to protect the fisheries-related resources of the coastal river basins, the wild spring Chinook populations in those basins are in decline and threatened with extinction.

Some of the relevant laws, policies, and efforts of these entities relevant to their work to achieve their intended purposes are summarized briefly below.

### a. State Environmental Policy Act

The Washington State Legislature enacted the State Environmental Policy Act (SEPA) in 1971. The law is intended to help state and local agencies identify environmental impacts that will likely result from projects and decisions such as construction of public and private projects and facilities, proposed policies or plans, such as a county or city plans, critical area ordinances, state water quality regulation, and other activities that may impact environmental resources. The SEPA is used to evaluate proposed decisions. Information learned through the review process can be used to change proposals to reduce likely impacts and to apply conditions to or deny proposals when adverse environmental impacts are identified.

A current application of SEPA in the Chehalis Basin pertains to the proposed Chehalis River Basin Flood Damage Reduction Project, i.e., the new large flood retention dam proposed for the upper Chehalis River at RM 108 (see description under National Environmental Policy Act). The Washington Department of Ecology (Ecology) issued a Draft Environmental Impact Statement for the project in February 2020. The Draft EIS was prepared to satisfy the requirements of SEPA. The purpose of the Draft EIS was to evaluate the probable significant environmental impacts from the construction and operation of the proposed project and its contribution to cumulative environmental impacts.

Some of the findings resported in the Draft EIS are listed below:

- Construction and operation of the proposed project would have a significant adverse impact on aquatic habitat from the headwaters of the Chehalis River to the middle mainstem. The removal of vegetation, increase in temperature, and reduced water quality would negatively affect aquatic habitat and species.

- Construction and operation of the proposed project would have significant adverse impacts on spring Chinook salmon from degraded habitat; fewer fish would survive passage around the proposed facility.
- Spring-run and fall-run Chinook would be most affected by a decline in habitat quality in the temporary reservoir area because their spawning is concentrated within this area.
- Spring Chinook spawn in three primary areas within the Chehalis Basin. The proposed project would significantly affect one of these three important spawning areas.
- These significant impacts on fish and aquatic species and habitat would be unavoidable unless mitigation plans meet regulatory requirements and implementation is feasible.
- The proposed project could reduce future restoration options in the subbasins above and below the proposed dam site and within the larger basin for the fish species and habitats they rely on.

The Draft EIS proposes mitigation to address adverse environmental impacts of the proposed project identified in the review—but in fact, the Draft EIS presented no mitigation plan.

Despite this, the Draft EIS states: "In some cases, implementation of mitigation measures would reduce but not completely eliminate the significant adverse impacts or the feasibility of mitigation is uncertain. These are identified in the Draft EIS as significant and unavoidable adverse environmental impacts for the following resource areas: Earth, Environmental Health and Safety, Fish Species and Habitat, Recreation, Wildlife Species and Habitat, Wetlands, and Water."

This contradictory statement implies that the authors of the Draft EIS realized that some of the impacts of the proposed project would be unmitigable, even though no mitigation plan was presented.

The Final EIS is still pending, although the process has been delayed due to modifications that are being made to the precise location of the proposed dam.

A decision to permit a new dam by Washington State that contributes to the extinction of imperiled spring Chinook would demonstrate the ineffectiveness of SEPA to protect salmon resources that should be listed under the ESA.

### b. Fishways Required in Dams and Around Unnatural Obstructions

The Washington State Legislature passed a law in 2003 that requires fish passage at dams and other unnatural obstructions to fish migration (RCW 77.57.030). The law states: "A dam or other obstruction across or in a stream shall be provided with a durable and efficient fishway approved by the director. Plans and specifications shall be provided to the department prior to the director's approval. The fishway shall be maintained in an effective condition and continuously supplied with sufficient water to freely pass fish." The director here refers to the director of WDFW.

Two high dams exist in the Chehalis Basin that block passage of Chinook salmon. The Skookumchuck Dam at RM 22 on the Skookumchuck River, built in 1970, blocked passage of spring Chinook to their historical spawning areas in that river (Finn 1973). No provision has been made for their passage since the dam was constructed. Even if consideration for passage was to be given now, it is important to note that most of their historical spawning habitat upstream of the dam is currently inundated by the reservoir upstream of the dam.

The other high dam is Wynoochee Dam on the upper Wynoochee River. It was built to provide fish passage. Adult Chinook were originally trapped at the base of the dam and trucked to the upper river. However, passing juvenile Chinook out of the reservoir to the river downstream was problematic and transportation of adult Chinook to the upper river was stopped. Spring Chinook, which were historically produced in the river (WDF 1955; Phinney and Bucknell 1975), have been extirpated in the Wynoochee River. Without effective passage both upstream and downstream of the dam, no possibility exists for a re-introduction and recovery in that river.

### c. Grays Harbor Basin Salmon Management

The Fish and Wildlife Commission consists of nine governor-appointed members that establishes policies for WDFW to preserve, protect, and perpetuate fish, wildlife, and related ecosystems of Washington state. One of the policies established is called Grays Harbor Basin Salmon Management (policy number C-3621). The objective of the policy is to advance the conservation and restoration of wild salmon in the Chehalis River Basin. With regard to spring Chinook, the policy appears to recognize the special needs of this population.

The policy needs to be updated to account for the current status of the spring Chinook population and help facilitate recovery actions.

### d. Chehalis Basin Strategy

In 2016 the Washington Legislature created the Office of Chehalis Basin within Ecology and established the Chehalis Basin Board. The office is responsible to develop and implement what is called the Chehalis Basin Strategy. The basin-wide strategy includes near- and long-term actions as well as small- and large-scale projects designed to achieve a two-pronged objective: Reduce flood-related damage while also restoring aquatic species habitat in the Chehalis River basin.

To achieve the objective of restoring aquatic species habitat in the basin, the Aquatic Species Restoration Plan (ASRP) was developed (ASRPSC 2019). The goal of the ASRP is create a comprehensive, science-based restoration plan that improves and protects habitats, ecosystem processes, and populations of salmon, and other native fish and aquatic species. This is a major initiative of Washington State and its partners in the effort, including the Quinault Indian Nation and the Chehalis Tribe. One of the highest priorities of the ASRP is to improve the status of spring Chinook in the basin—actions that seek to do that are being given high priority (ASRPSC 2019).

As part of the overall strategy, the other objective would address flood effects to human communities in the basin. As part of this effort, the Chehalis River Basin Flood Control Zone District has proposed the large dam and temporary reservoir in the upper Chehalis River at RM 108 (IEcology 2020).

The proposed dam would foreclose being able to restore the upper Chehalis River using modern restoration methods to rebuild the population segment produced there. A recovery plan for Chehalis River spring Chinook would need to target that area for restoration.

It bears noting that the Chehalis Basin Strategy has conflicting proposed actions, one of which is the major new dam at RM 108 and the other for restoring ecological processes and functions to that area.

### e. Washington Forest Practices Act

The Washington Forest Practices Act (WFPA) regulates timber harvest on state and private lands. Wash. Rev. Code §§ 76.09.010-.935. Among other goals, the WFPA seeks to "recognize both the public and private interest in the profitable growing and harvesting of timber," and "provide for regulation of forest practices so as to avoid unnecessary duplication in such rules," and "achieve compliance with all applicable requirements of federal and state law with respect to nonpoint sources of water pollution from forest practices." Wash. Rev. Code § 76.09.010(2)(c), (e), (g). The Act established a Forest Practices Board charged with adopting forest practice regulations, and it established a permit system operated by WDNR that covers certain forest practices. *Id.* §§ 76.090.030, 76.09.050, 76.09.020(7). The protections and inadequacies of the Washington Forest Practices Rules are discussed above undee the section on federal Habitat Conservation Plans.

#### f. Washington Coast Sustainable Salmon Plan

The Washington Coast Sustainable Salmon Partnership (WCSSP) was formed in 2008. The WCSSP published a Washington Coast Sustainable Salmon Plan in 2013 (WCSSP 2013). This plan has the following goals: maintain the region's salmon habitats and offshore waters in a condition that will sustain healthy salmon populations; ensure regional land use decisions are benign in regards to salmon habitat, or effectively mitigate for damage resulting from such decisions; regional hatchery practices will not impair wild fish populations and, where appropriate, will help to protect them; harvest of salmon – commercial, recreational, subsistence and ceremonial – will help to support vibrant economies and communities without negatively impacting the sustainability of salmon populations. It is important ot note that this plan does not provide any additional legal or regulatory protections for salmon or salmon habitat. The plan acknowledges that "there is significant uncertainty associated with long-term funding and authorization of actions identified in this Plan." The plan primarily provides education, communication, coordination, and outreach, serves as a hub for information, develops partnerships, and provides guidance for lead entities for habitat restoration and enhancement projects.

The WCSSP has delegated responsibility for salmon restoration planning, coordination and implementation to local partners, known as lead entities. Four Lead Entities cover five Water Resource Inventory Areas (WRIAs), four of which are within the range of Washington Coast spring-run Chinook. WRIA 20, called the Sol Duc–Hoh, is the area of the North Pacific Coast Lead Entity. For WRIA 20, the lead entity has published a Salmon Restoration Strategy (2010), which focuses on Lake Ozette Sockeye and bull trout, and Watershed Management Plan (2009), Detailed Implementation Plan (2010) a Hoh River Watershed Management Plan (2009) and Detailed Implementation Plan (2010). WRIA 21, called the Queets–Quinault, is the area of the Quinault Indian Nation Lead Entity. For WRIA 21, the lead entity has published a Queets/Quinault Watersheds Salmon Habitat Recovery Strategy (2010), which focuses on bull trout. Also in WRIA 21, the Quinault Indian Nation has published an Upper Quinault Restoration Plan, which focuses on increasing the quantity and quality of sockeye salmon spawning habitat in the Upper Quinault River floodplain. WRIAs 22 and 23, called respectively the Lower and Upper Chehalis, are the area of the Grays Harbor County Lead Entity, also known as the Chehalis Basin Lead Entity. For WRIAs 22 and 23, the lead entity has published a Chehalis Basin Salmon Habitat Restoration and Preservation Work Plan (2010), a Chehalis Basin Partnership Watershed Management Plan (2007-2008), and a Detailed Implementation Plan.

#### g. State Wildlife Action Plan

Washington State adopted a State Wildlife Action Plan in 2005, but coastal spring-run Chinook are not included or protected in this plan.

#### h. Salmon Monitoring

WDFW along with tribal biologists conduct annual monitoring of most coastal spring chinook populations, but there are significant data gaps.

The continued declines of Washington Coast spring-run Chinook salmon over the past couple decades despite the existence of state regulatory mechanisms, shows that Washington State management, including the co-management efforts by Washington State, lead entities, and the treaty tribes (Quinault, Hoh, and Quileute), are insufficient alone to adequately protect these populations. The protection and recovery mechanisms of the federal Eandangered Species Act are required to ensure that Washington Coast spring-run Chinook salmon are able to survive and recover.

## V. Request for Critical Habitat Designation

The Petitioners request the designation of critical habitat for Washington coast spring Chinook concurrent with listing. Critical habitat should encompass all known and potential freshwater spawning and rearing areas, migratory routes, estuarine habitats, riparian habitats and buffers, and essential near-shore ocean habitats.

## VI. References

Abatzoglou, J. T., Barbero, R., Wolf, J. W., & Holden, Z. A. 2014. Tracking Interannual Streamflow Variability with Drought Indices in the U.S. Pacific Northwest, Journal of Hydrometeorology, 15(5), 1900-1912. https://journals.ametsoc.org/view/journals/hydr/15/5/jhm-d-13-0167_1.xml

Abdul-Aziz, O.I., Mantua N.J, and Myers, K.W. 2011. Potential Climate Change Impacts on Thermal Habitats of Pacific Salmon (*Oncorhynchus* spp.) in the North Pacific Ocean and Adjacent Seas. Can. J. Fish. Aquatic Sci. 68:1660-1680.

Ahearn, A. 2015. Facing Rising Waters, A Native Tribe Takes Its Plea To Paris Climate Talks. NPR Special Series – Heating Up, December 2, 2015.

Allen, M.A. and T.J. Hassler. 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest)—Chinook Salmon. U.S. Fish & Wildlife Service Biological Report 82(11.49). U.S. Army Corps of Engineers, TR EL-82-4. 26 pp.

Arismendi, I., Safeeq, M., Dunham, J. B., and Johnson, S.L. 2014. Can Air Temperature Be Used to Project Influences of Climate Change on Stream Temperature? Environmental Research Letters 9(8):084015

ASRP Steering Committee (ASRPSC). 2019. Chehalis Basin Strategy Aquatic Species Restoration Plan. Aquatic Species Restoration Plan Steering Committee, Phase I - November 2019; Publication #19-06-009, Olympia, WA.

Atlas, W.I., Buehrens, T.W., McCubbing, D.J.F., Bison, R., and Moore, J.W. 2015. Implications of Spatial Contraction for Density Dependence and Conservation in A Depressed Population of Anadromous Fish. Canadian Journal of Fisheries and Aquatic Science, 72, 1682–1693.

Atlas, W.I., M.R. Sloat, W.H. Satterthwaite, T.W. Buehrens, C.K. Parken, J.W. Moore, N.J. Mantua, J. Hart, and A. Potapova. 2023. Trends in Chinook Salmon Spawner Abundance and Total Run Size Highlight Linkages Between Life History, Geography and Decline. Fish and Fisheries. 2023; 00:1–23. DOI: 10.1111/faf.12750

Baker, P.F., T.P. Speed and F.K. Ligon. 1995. Estimating the Influence of Temperature on the Survival of Chinook Salmon Smolts (*Oncorhynchus tshawytscha*) Migrating Through the Sacramento-San Joaquin River Delta of California. Canadian Journal of Fisheries and Aquatic Sciences 52(4):855–863.

Bakke, P. 2009. Physical Processes and Climate Change: A Guide for Biologists. Department of Interior, U.S. Fish and Wildlife Service. Unpublished report, revised April, 2009.Lacey, WA.

Beamesderfer, R. 2021. Integrated Analysis Limiting Factors and Opportunities for Improvement of Chehalis Salmon & Steelhead. Fish Science Solutions, Inc. Prepared for Chehalis Basin Board, WRCO, WDOE & WDFW.

Beechie T, Imake H, Greene J, Wade A, Wu H, Pess G, Roni P, Kimball J, Stanford J, Kiffney P, Mantua N. 2013. Restoring Salmon Habitat for a Changing Climate. River Research and Applications 29: 939-960.

Beechie, T.J., C. Nicol, C. Fogel, J. Jorgensen, J. Thompson, G. Seixas, J. Chamberlin, J. Hall, B. Timpane-Padgham, P. Kiffney, S. Kubo, and J. Keaton. 2021. Modeling Effects of Habitat Change and Restoration Alternatives on Salmon in the Chehalis River Basin Using a Salmonid Life-Cycle Model. U.S. Department of Commerce, NOAA Contract Report NMFS-NWFSC-CR-2021-01.

Belchik, M. 2003. Use of Thermal Refugial Areas on the Klamath River by Juvenile Salmonids; Summer 1998. Yurok Tribal Fisheries Program Technical Report, 36. Klamath, CA. 36 pp.

Berg, D.R., A. McKee, and M.J. Maki. 2003. Restoring Floodplain Forests. Pages 248-291 *in* D.R. Montgomery, S. Bolton, D.B. Booth, and L. Wall (eds.) Restoration of Puget Sound Rivers. University of Washington Press, Seattle, WA.

Berman, C.H. and Quinn, T.P. 1991. Behavioural Thermoregulation and Homing by Spring Chinook Salmon, *Oncorhynchus tshawytscha* (Walbaum), in the Yakima River. Journal of Fish Biology 39:301– 312.

Bisson, P.A., Quinn, T.P., Reeves, G.H., and S.V. Gregory. 1992. Best Management Practices, Cumulative Effects, and Long-Term Trends in Fish Abundance in Pacific Northwest River Systems. In Watershed Management: Balancing Sustainability and Environmental Change, ed. Robert J. Naiman, pp. 189-232. Springer-Verlag, New York.

Bodi, F.L. and E. Erdheim. 1986. Swimming Upstream: FERC's Failure to Protect Anadromous Fish. Ecology Law Quarterly 13:1.

Bowerman, T.E., Keefer, M.L., and Caudill, C.C. 2021. Elevated stream temperature, origin, and individual size influence Chinook salmon prespawn mortality across the Columbia River Basin. Fish. Res. 237(January): 105874. Elsevier B.V. doi:10.1016/j.fishres.2021.105874.

Brennan, S.R., Schindler, D.E., Cline, T.J., Walsworth, T.E., Buck, G., and Fernandez, D.P. 2019. Shifting Habitat Mosaics and Fish Production Across River Basins. Science 364(6442):783-786.

Brown, B. 1982. Mountain in the Clouds - A Search for the Wild Salmon. Simon and Shuster, New York, NY.

Buchanan, J. B. 2016. Periodic Status Review for the Northern Spotted Owl in Washington. Washington Department of Fish and Wildlife, Olympia, Washington. 22 + iv pp

Burner, C.J. 1951. Characteristics of Spawning Nests of Columbia River Salmon. Fishery Bulletin 61:97-110. U.S. Fish and Wildlife Service.

Busby, P.J., Wainwright T.C., Bryant G.J., et al. 1996. Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-27. Seattle, WA.

Busch DS, Harvey CJ, McElhany P. 2013. Potential Impacts of Ocean Acidification on the Puget Sound Food Web. ICES J Mar Sci. 70(4):823–33.

Carlson, S.M. and T.R. Seamons. 2008. A Review of Quantitative Genetic Components of Fitness in Salmonids: Implications for Adaptation to Future Change. Evolutionary Applications 1 (2), 222-238

Carlson, S.M. and Satterthwaite, W.H. 2011. Weakened Portfolio Effect in a Collapsed Salmon Population Complex. Canadian Journal of Fisheries and Aquatic Sciences 68(9):1579-1589.

Cederholm C.J., and L.M. Reid. 1987. Impact of forest management on Coho salmon (*Oncorhynchus kisutch*) populations of the Clearwater River, Washington: a project summary. Pages 373-398 *in* Salo E.O., and T.W. Cundy (eds) Streamside Management Forestry and Fishery Interactions. College of Forest Resources, University of Washington, Seattle, WA.

Cederholm, C.J., L.M. Reid, and E.O. Salo. 1980. Cumulative effects of logging road sediment on salmonid populations in the Clearwater River, Jefferson County, Washington. In Proceedings from the conference Salmon Spawning Gravel: A Renewable Resource in the Pacific Northwest? College of Fisheries, University of Washington, Seattle.

Cederholm, C.J., R.E. Bilby, P.A. Bisson, T.W. Bumstead, B.R. Fransen, W.J. Scarlett, and J.W. Ward. 1997. Response of juvenile coho salmon and steelhead to placement of large woody debris in a coastal Washington stream. North American Journal of Fisheries Management 17(4):947–963.

Cederholm, C.J., Kunze, M.D., Murota, T., and Sibatani, A. 1999. Pacific Salmon Carcasses: Essential Contributions of Nutrients and Energy for Aquatic and Terrestrial Ecosystems. Fisheries, 24(10), 6-15.

Chamberlin, P.W. 1982. Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America: Timber Harvest. General Technical Report PNW-136. Pacific Northwest Forest and Range Experiment Station, U.S. Forest Service, Portland, OR.

Chehalis Basin Partnership, 2004. Chehalis Basin Watershed Management Plan. https://chehalisbasinpartnership.org/watershed-management-plan-documents/

Cheung, W.W.L., and T.L. Frölicher. 2020. Marine Heatwaves Exacerbate Climate Change Impacts for Fisheries in the Northeast Pacific. Sci Rep 10, 6678.

Chilcote, M.W., Goodson, K.W., and M.R. Falcy. 2011. Reduced Recruitment Performance in Natural Populations of Anadromous Salmonids Associated with Hatchery-Reared Fish. Canadian Journal of Fisheries and Aquatic Sciences 68(3):511-522.

Chinook Technical Committee (CTC). 2012. 2011 Exploitation Rate Analysis and Model Calibration. Pacific Salmon Commission Joint Chinook Technical Committee Report TCCHINOOK (12)-2. Vancouver, BC.

Chinook Technical Committee (CTC). 2023. 2022 Exploitation Rate Analysis. Pacific Salmon Commission Joint Chinook Technical Committee Report TCCHINOOK (23)-01. Vancouver, BC.

Christie, M.R., M.J. Ford, and M.S. Blouin. 2014. On the Reproductive Success of Early-Generation Hatchery Fish in the Wild. Evolutionary Applications, 7, 883–896. 10.1111/eva.12183

Climate Impacts Group (CIG). 2009. The Washington Climate Change Impacts Assessment, M. McGuire Elsner, J. Littell, and L Whitely Binder (eds). Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, Washington. Available at: http://www.cses.washington.edu/db/pdf/wacciareport681.pdf

Cobb, J. N. 1930. Pacific Salmon Fisheries. Document No. 1092. U.S. Bureau of Fisheries, Washington, DC.

Collins, B.D., Dickerson-Lange, S.E., Schanz, S. and Harrington, S. 2019. Differentiating the Effects of Logging, River Engineering, and Hydropower Dams on Flooding in the Skokomish River, Washington, USA. Geomorphology, 332, pp.138-156.

Collins, E.E., Hargrove J.S., Delomas T.A., and Narum S.R.. 2020. Distribution of Genetic Variation Underlying Adult Migration Timing in Steelhead of the Columbia River Basin. Ecol Evol. 10:9486–9502

Crozier, L.G. and R.W. Zabel. 2006. Climate Impacts at Multiple Scales: Evidence for Differential Population Responses in Juvenile Chinook Salmon. Journal of Animal Ecology, 75: 1100- 1109.

Crozier, L.G., Hendry, A.P., Lawson, P.W., Quinn, T.P., Mantua, N.J., Battin, J., Shaw, R.G. and Huey, R.B. 2008. Potential Responses to Climate Change in Organisms with Complex Life Histories: Evolution and Plasticity in Pacific Salmon. Evolutionary Applications, 1: 252- 270.

Dalton, M.M., P.W. Mote, and A.K. Snover [Eds.]. 2013. Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities. Washington, DC, Island Press. 271 pp.

Dalton, M.M, L. Benda, M. Case, S. Chisholm Hatfield, N. Cohn, M. Conlin, J. Lawler, P. Mote, D. Sharp, G. Reeves, P. Ruggiero, and K. Serafin. 2016. Climate Change Vulnerability Assessment for the Treaty of Olympia Tribes: A Report to the Quinault Indian Nation, Hoh Tribe, and Quileute Tribe. Oregon Climate Change Research Institute, Corvallis, OR.

Davis, R.J., B. Hollen, J. Hobson, J.E. Gower and D. Keenum. 2016. Northwest Forest Plan—the First 20 Years (1994–2013): Status and Trends of Northern Spotted Owl Habitats. Gen. Tech. Rep. PNW-GTR-929. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Devine, W.D., Minkova, T., Martens, K.D., Keck, J., Foster, A.D. 2022. Status and trends monitoring of riparian and aquatic habitat in the Olympic Experimental State Forest: 2013-2020 results. Washington State Department of Natural Resources, Forest Resources Division, Olympia, WA.

Dominguez, L. 2006. Predictions of coho salmon (*Oncorhynchus kisutch*) population abundance in the Clearwater River, Washington using various habitat-rating scenarios of the Ecosystem Diagnosis and Treatment Method. Master's Thesis, Evergreen State College, Olympia, WA.

Dornbush, P. 2013. ESA Recovery Plan for: Lower Columbia River Coho Salmon, Lower Columbia River Chinook Salmon, Lower Columbia River Chum Salmon, and Lower Columbia River Steelhead. Portland, OR: National Marine Fisheries Service. 503 pp.

Duda, J.J., S.J. Brenkman, and P. Crain. 2018. Ch. 4: Pacific Salmonids. Pages 123-167 in R. McCaffery and K. Jenkins, editors. Natural Resource Condition Assessment: Olympic National Park. Natural Resource Report NPS/OLYM/NRR—2018/1826. National Park Service, Fort Collins, Colorado.

East, A. E., Jenkins, K. J., Happe, P. J., Bountry, J. A., Beechie, T. J., Mastin, M. C., Sankey, J. B., and Randle, T. J. 2017. Channel-Planform Evolution in Four Rivers of Olympic National Park, Washington, USA: the roles of physical drivers and trophic cascades. Earth Surf. Process. Landforms, 42: 1011– 1032.

Ebersole, J.L., Liss, W.J., and Frissell, C.A. 2003. Thermal Heterogeneity, Stream Channel Morphology, and Salmonid Abundance in Northeastern Oregon Streams. Canadian Journal of Fisheries and Aquatic Sciences 60(10):1266-1280.

Einum, S., Nislow, K. H., Reynolds, J. D. and Sutherland, W. J. 2008. Predicting Population Responses to Restoration of Breeding Habitat in Atlantic Salmon. Journal of Applied Ecology, 45: 930-938. doi:10.1111/j.1365-2664.2008.01464.x

Elsner, M.M., L. Cuo, N. Viosin, J.S. Deems, A.F. Hamlet, J.A. Vano, D.P. Lettenmaier. 2010. Implications of 21st Century Climate Change for the Hydrology of Washington State. Climatic Change 102(1): 225-260.

Everest, F. and D. Harr. 1982. Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America: Silvicultural Treatments. General Technical Report PNW-134. Pacific Northwest Forest and Range Experiment Station, U.S. Forest Service, Portland, OR.

Field, R D. and Reynolds, J.D. 2013. Ecological Links Between Salmon, Large Carnivore Predation, and Scavenging Birds. Journal of Avian Biology 44(1):009-016.

Finn, E.L. Jr. 1973. Skookumchuck-Hanaford Creek fisheries investigations. Final report. Washington Department of Fisheries. Olympia, WA.

Finstad, A.G., Sættem, L.M., and S. Einum, 2013. Historical Abundance and Spatial Distributions of Spawners Determine Juvenile Habitat Accessibility in Salmon: Implications for the Population Dynamics and Management Targets. Canadian Journal of Fisheries and Aquatic Sciences 70:1339–1345.

Ford, J.K.B., and G.M. Ellis. 2006. Selective Foraging by Fish-Eating Killer Whales *Orcinus orca* in British Columbia. Marine Ecology - Progress Series 316:185-199.

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

Ford M.J., Anderson E., Garza J.C., Myers J., Williams T.H., and Waples R. 2021. Report on a Review of the Oregon Coast and Southern Oregon Northern California Coastal Spring Chinook Salmon ESU Configuration. Northwest Fisheries Science Center, National Marine Fisheries Service.

Fountain, A.G., Gray, C., Glenn, B., Menounos, B., Pflug, J., & Riedel, J. L. 2022. Glaciers of the Olympic Mountains, Washington—The Past and Future 100 years. Journal of Geophysical Research: Earth Surface, 127, e2022JF006670. H

Frachtenberg, L.J. 1916. Quileute Ethnology: LaPush, Washington. (Field notebooks, manuscript No. E0 (W3a5). [Freeman No. 3177] in American Philosophical Society Library, Philadelphia.

Frachtenberg, L.J. 1921. The Ceremonial Societies of the Quileute Indians. American Anthropologist 23(3):320-352.

Frissell, C.A., R.J. Baker, D.A. DellaSala, R.M. Hughes, J.R. Karr, D.A. McCullough, R.K. Nawa, J. Rhodes, M.C. Scurlock, and R.C. Wissmar. 2014. Conservation of aquatic and fishery resources in the Pacific Northwest: implications of new science for the aquatic conservation strategy of the Northwest Forest Plan – final report. Coast Range Association. 35p.

Fullerton, A.H., Torgersen, C.E., Lawler, J.J., Faux, R.N., Steel, E.A., Beechie, T.J., and Leibowitz, S.G. 2015. Rethinking the Longitudinal Stream Temperature Paradigm: Region-Wide Comparison of Thermal Infrared Imagery Reveals Unexpected Complexity of River Temperatures. Hydrological Processes 29(22), 4719-4737.

Gaines, W.L., P.F. Hessburg, G.H. Aplet, P. Henson, S.J. Prichard, D.J. Churchill, G.M. Jones, D.J. Isaak, and C. Vynne. 2022. Climate Change and Forest Management on Federal Lands in the Pacific Northwest, USA: Managing for Dynamic Landscapes. Forest Ecology and Management, Volume 504.

Gilbertson, L., T. Jurasin, R. Coshow, and M. Miller, 2021. Run-Type Composition of Juvenile Chinook Salmon in the Upper Chehalis River Basin in 2020. Technical Report Series 2021-1, Quinault Indian Nation Department of Fisheries, July 2021. Taholah, WA.

Giles, D.A., and others. 2018. Letter to Governor Jay Inslee and Co-Chairs Solien and Purce and Southern Resident Orca Recovery Task Force Members. Letter dated October 15, 2018.

Goniea, T.M., Keefer, M.L., Bjornn, T.C., Peery, C.A., Bennett, D.H., and Stuehrenberg, L.C. 2006. Behavioral Thermoregulation and Slowed Migration by Adult Fall Chinook Salmon in Response to High Columbia River Water Temperatures. Transactions of the American Fisheries Society 135(2):408-419.

Good, J.W. 2000. Oregon State of the Environment Report 2000. Oregon Progress Board, State of Oregon Environmental Report Science Panel, Salem, OR. 20 pp.

Good, T.P., Davies, J., Burke, B.J., and Ruckelshaus, M.H. 2008. Incorporating Catastrophic Risk Assessments into Setting Conservation Goals for Threatened Pacific Salmon. Ecological Applications 18(1):246-257.

Gresh, T., Lichatowich, J., and Schoonmaker, P. 2000. An Estimation of Historic and Current Levels of Salmon Production in the Northeast Pacific Ecosystem: Evidence of a Nutrient Deficit in the Freshwater Systems of the Pacific Northwest. Fisheries 25(1):15-21.

Gustafson, R.G., Waples, R.S., Myers, J.M., Weitkamp, L.A., Bryant, G.J., Johnson, O.W., and Hard, J.J. 2007. Pacific Salmon Extinctions: Quantifying Lost and Remaining Diversity. Conservation Biology 21(4), 1009-1020.

Halofsky, Jessica E.; Peterson, David L.; O'Halloran, Kathy A.; Hawkins Hoffman, Catherine, eds. 2011. Adapting to Climate Change at Olympic National Forest and Olympic National Park. Gen. Tech. Rep. PNW-GTR-844. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 130 p.

Hard, J. J., Gross, M. R., Heino, M., Hilborn, R., Kope, R. G., Law, R., and J.D. Reynolds. 2008. Evolutionary Consequences of Fishing and Their Implications for Salmon. Evolutionary applications, 1(2), 388–408. doi:10.1111/j.1752-4571.2008.00020.x

Hard, J.J., Myers J.M., Connor E.J., Hayman R.A., Kope R.G., Lucchetti G., Marshall A.R., Pess G.R., and Thomson B.E. 2015. Viability Criteria for Steelhead Within the Puget Sound Distinct Population Segment. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-129, 332 pp.

Healey, M.C. 1983. Coastwide Distribution and Ocean Migration Patterns of Stream- and Ocean-Type Chinook Salmon, *Oncorhynchus tshawytscha*. Can Field Nat. 97:427–433.

Healey, M.C. 1991. Life History of Chinook Salmon. Pp. 311-349 In: C. Groot and L. Margolis (eds.) Pacific Salmon Life Histories. University of British Columbia Press. Vancouver, BC, Canada.

Hemstrom W., van de Wetering S., and Banks M. 2018. Fish Ladder Installation Across a Historical Barrier Asymmetrically Increased Conspecific Introgressive Hybridization Between Wild Winter and Summer Run Steelhead Salmon in the Siletz River, Oregon. Can J Fish Aquat Sci. 75:1383–1392.

Hendry, A.P., Day, T. and Cooper, A.B. 2001. Optimal size and number of propagules: allowance for discrete stages and effects of maternal size on reproductive output and offspring fitness. The American Naturalist, 157(4), pp.387-407.

Hess, J.E., Zendt, J.S., Matala, A.R., and Narum, S.R. 2016. Genetic Basis of Adult Migration Timing in Anadromous Steelhead Discovered Through Multivariate Association Testing. Proceedings of the Royal Society B: Biological Sciences 283(1830), 20153064.

Hilborn, R. 1985. Apparent Stock Recruitment Relationships in Mixed Stock Fisheries. Canadian Journal of Fisheries and Aquatic Sciences 42(4):718-723.

Hiss, J.M., and E.E. Knudsen. 1993. Chehalis River Basin Fishery Resources: Status, Trends, and Restoration. U.S. Fish and Wildlife Service Western Washington Fishery Resource Office. Olympia, WA.

Hiss, J.M., Meyer J.H., and Boomer R.S. 1985. Chehalis Spring Chinook Progress Report 1984. U.S. Fish and Wildlife Service Western Washington Fishery Resource Office. Olympia, WA..

Hiss, J., J. Meyer, and R. Boomer. 1982. Status of Chehalis River salmon and steelhead fisheries and problems affecting the Chehalis Tribe. U.S. Fish and Wildlife Service Western Washington Fishery Resource Office. Olympia, WA.

Hatchery Scientific Review Group (HSRG) – Lars Mobrand (chair), John Barr, Lee Blankenship, Don Campton, Trevor Evelyn, Tom Flagg, Conrad Mahnken, Robert Piper, Paul Seidel, Lisa Seeb and Bill Smoker. April 2004. Hatchery Reform: Principles and Recommendations of the HSRG. Long Live the Kings, 1305 Fourth Avenue, Suite 810, Seattle, WA 98101 (available from www.hatcheryreform.org).

Hatchery Scientific Review Group (HSRG). 2014. On the Science of Hatcheries: An updated perspective on the role of hatcheries in salmon and steelhead management in the Pacific Northwest. A. Appleby, H.L. Blankenship, D. Campton, K. Currens, T. Evelyn, D. Fast, T. Flagg, J. Gislason, P. Kline, C. Mahnken, B. Missildine, L. Mobrand, G. Nandor, P. Paquet, S. Patterson, L. Seeb, S. Smith, and K. Warheit. June 2014; revised October 2014.

Hulse, D., S. Gregory, and J. Baker. 2002. Willamette River Basin Planning Atlas. Oregon State University Press, Corvallis, OR. https://www.fsl.orst.edu/pnwerc/wrb/Atlas_web_compressed/PDFtoc.html

Hunter, J.W. 2006. Quillayute Watershed Prioritized Salmon Restoration Projects. Report prepared for Quileute Natural Resources, LaPush WA.

Huntington, C.W., W. Nehlsen, and J. Bowers. 1994. Healthy Stocks of Anadromous Salmonids in the Pacific Northwest and California. Oregon Trout, Portland, OR.

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

Intergovernmental Panel on Climate Change (IPCC). 2022. 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3–33, doi:10.1017/9781009325844.001. https://www.ipcc.ch/report/ar6/wg2/chapter/summary-for-policymakers/

Isaak, D.J., and Rieman, B.E. 2013. Stream Isotherm Shifts from Climate Change and Implications for Distributions of Ectothermic Organisms. Global Change Biology, 19(3):742-751.

Isaak, D.J., Wollrab, S., Horan, D., and Chandler, G. 2012. Climate Change Effects on Stream and River Temperatures Across the Northwest US from 1980–2009 and Implications for Salmonid Fishes. Climatic Change 113(2):499-524.

Isaak, D.J., Luce, C.H., Horan, D.L., Chandler, G.L., Wollrab, S.P., and Nagel, D.E. 2018. Global Warming of Salmon and Trout Rivers in the Northwestern US: Road to Ruin or Path Through Purgatory? Transactions of the American Fisheries Society 147(3):566-587.

James, Jr., J. 2000. Salmon River Watershed Analysis - Cultural and Human Uses Module. In Salmon River Watershed Analysis. Quinault Department of Natural Resources Taholah, WA.

Joh, Y., E. Di Lorenzo. 2017. Increasing Coupling Between NPGO and PDO Leads to Prolonged Marine Heatwaves in the Northeast Pacific. Geophys. Res. Lett., 44, 11,663-11,671.

Jones, J.A. and D.A. Post. 2004. Seasonal and Successional Streamflow Response to Forest Cutting and Regrowth in the Northwest and Eastern United States. Water Resources Research 40(5):W05203, doi:10.1029/2003WR002952

Kauffman, D.E. 1951. Research report on the Washington State offshore troll fishery. Pacific Marine Fisheries Commission Bulletin. 2:77-91.

Kelsey, D.A., C.B. Schreck, J.L. Congleton and L.E. Davis. 2002. Effects of Juvenile Steelhead on Juvenile Chinook Salmon Behaviour and Physiology. Transactions of the American Fisheries Society 131: 676-689.

Kilduff, D.P., Di Lorenzo, E., Botsford, L.W., and Teo, S. L. 2015. Changing Central Pacific El Niños Reduce Stability of North American Salmon Survival Rates. Proceedings of the National Academy of Sciences112(35):10962-10966.

Kinziger, A.P., Loudenslager, E.J., Hankin, D.G., Anderson, E.C., and Garza, J.C. 2008. Hybridization between spring-and fall-run Chinook salmon returning to the Trinity River, California. North American Journal of Fisheries Management, 28(5), 1426-1438.

Kliem, J.M. and D.A. Holden. 2011. The Chehalis Basin Salmon Habitat Restoration and Preservation Strategy for WRIA 22 and 23. Creative Community Solutions, Inc. Prepared by Grays Harbor County Lead Entity Habitat Work Group.

Klinger, T., R.M. Gregg, K. Herrmann, K. Hoffman, J. Kershner, J. Coyle, and D. Fluharty. 2008. Assessment of Coastal Water Resources and Watershed Conditions at Olympic National Park, Washington. Natural Resource Technical Report NPS/NRPC/WRD/NRTR—2008/068. National Park Service, Fort Collins, Colorado.

Koch, I.J. and S.R. Narum. 2020. Validation and Association of Candidate Markers for Adult Migration Timing and Fitness in Chinook Salmon. Evol Appl. 13:2316–2332.

Kohn, M., C. Warnock, and P. Rittmueller. 2009. Elevated River Temperatures Result in Salmon Kills in the Chehalis River Basin -- Summary of fisheries investigation July 30 - August 27, 2009. Informal note prepared jointly by Lewis County PUD and EES Consulting, Inc.

Kostow, K. (Editor). 1995. Biennial Report on the Status of Wild Fish in Oregon. Oregon Dep. Fish Wildl., Portland. 217 pp. plus 1 appendix.

Kunkel, K. E., L. E. Stevens, S. E. Stevens, L. Sun, E. Janssen, D. Wuebbles, K. T. Redmond, and J. G. Dobson, 2013: Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 6. Climate of the Northwest U.S. NOAA Technical Report NESDIS 142-6. 75 pp.

Lance, M.M., and S.F. Pearson. 2021. Washington 2020 At-Sea Marbled Murrelet Population Monitoring: Research Progress Report. Washington Department of Fish and Wildlife, Wildlife Science Division.

Landscape Climate Dashboard (LCD). 2022. Climate Projections for Federally and Tribally Protected Lands of the West: Olympic National Park. http://www.climatedashboard.org/

Lasorsa, D. 2002. Salmon River watershed analysis - riparian module. *In* Salmon River Watershed Analysis. Quinault Dept. Natural Resources Taholah, Washington.

Lestelle, L. 2009. Strategic priorities for habitat management to improve the freshwater performance of Queets coho salmon. Report submitted to the Quinault Indian Nation, Taholah, WA.

Lestelle, L.C., and J.P. Blum. 1989. Assessment of damages to the fisheries resources of the Quinault Reservation due to logging practices administered by the Bureau of Indian Affairs.

Report prepared for the Quinault Business Committee and submitted to the U.S. Departments of Interior and Justice. Quinault Department of Natural Resources, Taholah, WA.

Lestelle, L.C., and C.J. Cederholm. 1984. The effects of forest debris removal on the cutthroat trout population of a small stream. *In* W. Meehan, T. Merrell, Jr., and T. Hanley (eds). Fish and Wildlife Relationships in Old-Growth Forests. Proceedings of symposium sponsored by the American Institute of Fishery Biologists, the Wildlife Society, and the Alaska Council of Science and Technology, April, 1982.

Lestelle, L.C., W.E. McConnaha, G. Blair, and B. Watson. 2005. Chinook salmon use of floodplain, secondary channel, and non-natal tributary habitats in rivers of western North America. Report prepared for the Mid-Willamette Valley Council of Governments, U.S. Army Corps of Engineers, and Oregon Department of Fish and Wildlife. Mobrand-Jones and Stokes, Vashon, WA and Portland, OR.

Lestelle, L., M. Zimmerman, C. McConnaha, and J. Ferguson, 2019. Spawning Distribution of Chehalis Spring-Run Chinook Salmon and Application to Modeling. Memorandum to Aquatic Species Restoration Plan Science and Review Team. April 8, 2019.

Letelier, R.M., Björkman, K.M., Church, M.J., Hamilton, D.S., Mahowald, N.M., Scanza, R.A., and Karl, D.M. 2019. Climate-Driven Oscillation of Phosphorus and Iron Limitation in the North Pacific Subtropical Gyre. Proceedings of the National Academy of Sciences 116(26):12720-12728. https://www.pnas.org/doi/full/10.1073/pnas.1900789116

Lichatowich, J.A., and L.E. Mobrand. 1995. Analysis of Chinook salmon in the Columbia River from an ecosystem perspective. U.S. Department of Energy Bonneville Power Administration, Environment Fish and Wildlife. DOE/BP-25105-2.

Liedtke, T.L., M.S. Zimmerman, R.G. Tomka, C. Holt, and L. Jennings. 2016. Behavior and movements of adult spring Chinook salmon (Oncorhynchus tshawytscha) in the Chehalis River Basin, southwestern Washington, 2015, 2016-1158, Reston, VA, http://dx.doi.org/10.3133/ofr20161158.

Luce, C.H. and Z.A. Holden. 2009. Declining Annual Streamflow Distributions in the Pacific Northwest United States, 1948–2006. Geophysical Research Letters 36(16).

Malcomb, Nathan L., and Gregory C. Wiles. "Tree-ring-based reconstructions of North American glacier mass balance through the Little Ice Age—Contemporary warming transition." Quaternary Research 79.2 (2013): 123-137.

Manhard, C.V., Joyce, J.E., and A.J. Gharrett. 2017. Evolution of Phenology in a Salmonid Population: A Potential Adaptive Response to Climate Change. Canadian Journal of Fisheries and Aquatic Sciences 74(10): 1519-1527. https://doi.org/10.1139/cjfas-2017-0028

Mantua, N.J., S.R. Hare, Y. Zhang, J.M. Wallace, and R.C. Francis 1997: A Pacific Interdecadal Climate Oscillation with Impacts on Salmon Production. Bulletin of the American Meteorological Society, 78, pp. 1069-1079.

Mantua, N., I. Tohver, and A. Hamlet. 2010. Climate Change Impacts on Streamflow Extremes and Summertime Stream Temperature and Their Possible Consequences for Freshwater Salmon Habitat in Washington State. Climatic Change 102:187-223.

Mantua, N.J., R. Metzger, P. Crain, S. Brenkman, and J.E. Halofsky. 2011. Climate Change, Fish, and Fish Habitat Management at Olympic National Forest and Olympic National Park. In: Halofsky J, Peterson D, O'Halloran K, Hoffman C (eds) Adapting to Climate Change at Olympic National Forest and Olympic National Park. General technical report PNW-GTR-844. US Forest Service, Portland, OR.

Martens, K.D. and W.D. Devine. 2022. Pool Formation and the Role of Instream Wood in Small Streams in Predominantly Second-Growth Forests. Environmental Management.

Martens, K.D., Devine, W.D., Minkova, T.V. and A.D. Foster. 2019. Stream Conditions After 18 Years of Passive Riparian Restoration in Small Fish-Bearing Watersheds. Environmental Management 63: 673-690.

Mathis, J.T., J.N. Cross, W. Evans, and S.C. Doney. 2015. Ocean Acidification in the Surface Waters of the Pacific-Arctic Boundary Regions. Oceanography 28(2):122–135.

Mattson, R.W., and R.W. Klinge. 1976. Hoh Tribal Fisheries Program Annual Report No. 1. Fiscal Year 76. December 1976, Contract No. 14-20-0500-4797.

McConnaha, W., J. Walker, K. Dickman, M. Yelin 2017. Analysis of Salmonid Habitat Potential to Support the Chehalis Basin Programmatic Environmental Impact Statement. Prepared by ICF Portland, OR for Anchor QEA, Seattle, WA.

McCullough, D.A. 1999. A Review and Synthesis of Effects of Alterations of the Water Temperature Regime on Freshwater Life Stages of Salmonids, With Special Reference to Chinook Salmon. EPA910-R-99-010. Region 10, U.S. Environmental Protection Agency, Seattle, WA. p. 279.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-42.

McElhany, P., Busack C., Chilcote M., Kolmes S., McIntosh B., Myers J., Rawding D., Steel E., Steward C., Ward D., et al. 2006. Revised Viability Criteria for Salmon and Steelhead in the Willamette and Lower Columbia Basins. Review Draft. April 1, 2006. p. 178.

McHenry, M.J., J.A. Lichatowich J., and R. Kowalski-Hagaman. 1996. Status of Pacific Salmon and Their Habitats on the Olympic Peninsula, Washington. Report to the Lower Elwha Klallam Tribe, Port Angeles, WA.

McHenry, M.L., E. Shott, R.H. Conrad, and G.B. Grette. 1998. Changes in the quantity and characteristics of large woody debris in streams of the Olympic Peninsula, Washington, U.S.A. (1982-1993). Canadian Journal of Fisheries and Aquatic Science. 55:1395–1407.

McIver, William R.; Pearson, Scott F.; Strong, Craig; Lance, Monique M.; Baldwin, Jim; Lynch, Deanna; Raphael, Martin G.; Young, Richard D.; Johnson, Nels. 2021. Status and Trend of Marbled Murrelet Populations in the Northwest Forest Plan Area, 2000 to 2018. Gen. Tech. Rep. PNW-GTR-996. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 37 p.

McMillan, J.R. and J.C. Starr. 2008. Identification and Prioritization of Salmon Tributaries for Conservation in the Hoh River Basin, Washington State. Wild Salmon Center, Portland, Oregon.

McMillan, J.R., M. C. Liermann, J. Starr, G. R. Pess, and X. Augerot. 2013. Using a Stream Network Census of Fish and Habitat to Assess Models of Juvenile Salmonid Distribution. Transactions of the American Fisheries Society 142:942–956.

Meehan, W.R., and T.C. Bjornn. 1991. Salmonid Distributions and Life Histories. Pages 47-82 in Meehan, W.R. (editor). Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. Special publication 19. American Fisheries Society, Bethesda, MD.

Micheletti, S.J., Hess, J.E., Zendt, J.S. et al. 2018. Selection at a Genomic Region of Major Effect is Responsible for Evolution of Complex Life Histories in Anadromous Steelhead. BMC Evol Biol. 18:140.

Miller, I.M., Shishido, C., Antrim, L, and Bowlby, C.E. 2013. Climate Change and the Olympic Coast National Marine Sanctuary: Interpreting Potential Futures. Marine Sanctuaries 153 Conservation Series ONMS-13-01. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 238 pp.

Minakawa, N., Gara, R. I., and Honea, J. M. 2002. Increased Individual Growth Rate and Community Biomass of Stream Insects Associated with Salmon Carcasses. Journal of the North American Benthological Society 21(4):651-659.

Montgomery, D.R., E.M. Beamer, G.R. Pess and T.P. Quinn. 1999. Channel Type and Salmonid Spawning Distribution and Abundance. Canadian Journal of Fisheries and Aquatic Sciences 56(3):377–387.

Moore, J.W., Yeakel, J.D., Peard, D., Lough, J., and Beere, M. 2014. Life-History Diversity and its Importance to Population Stability and Persistence of a Migratory Fish: Steelhead in Two Large North American Watersheds. Journal of Animal Ecology, 83(5), 1035-1046.

Moore, J.W., McClure, M., Rogers, L.A., and Schindler, D.E. 2010. Synchronization and Portfolio Performance of Threatened Salmon. Conservation Letters 3(5):340-348.

Moran, P., Dazey, J., LaVoy, L., and Young, S. 2018. Genetic Mixture Analysis Supports Recalibration of the Fishery Regulation Assessment Model. *Fisheries*, *43*(2), 83-97.

Morishima, G.S. 1984. Wild Fish: Realities of Management. Pages 115-122 *in* J.M. Walton and D.B. Houston, editors. Olympic wild fish conference. Peninsula College, Port Angeles, WA.

Morishima, G.S., and K.A. Henry. 2000. The history and status of Pacific Northwest Chinook and coho salmon ocean fisheries and prospects for sustainability. Pages 219–235 in E.E. Knudsen, C.R. Steward, D.D. McDonald, J.E. Williams, and D.W. Reiser (eds.) Sustainable Fisheries Management: Pacific Salmon. CRC Press.

Morriss, A.P., B. Yandle and R.E. Meiners. 2001. The Failure of EPA's Water Quality Reforms: From Environment-Enhancing Competition to Uniformity and Polluter Profits. 20 UCLA Journal of Environmental Law and Policy 25 (2001). Texas A&M University School of Law, Texas A&M Law Scholarship.

Mote, P. W., and E.P. Salathé. 2010. Future Climate in the Pacific Northwest. Climatic Change 102(1-2): 29-50.

Moyle, P.B. 2002. Inland Fishes of California, 2nd Edition. Berkeley, CA: University of California Press. 502 pp.

Moyle, P.B., R.M. Yoshiyama, J.E. Williams and E.D. Wikrananayake. 1995. Fish Species of Special Concern of California, 2nd Ed. California Department of Fish and Game, Sacramento, CA.

Moyle, P.B., J.A. Israel and S.E. Purdy. 2008. Salmon, Steelhead, and Trout in California, Status of an Emblematic Fauna: A Report Commissioned by California Trout. Center for Watershed Sciences, University of California, Davis.

Muñoz, N.J., Farrell, A P., Heath, J.W., and Neff, B.D. 2015. Adaptive Potential of a Pacific Salmon Challenged by Climate Change. Nature Climate Change 5(2):163.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-35. National Marine Fisheries Service. Seattle, WA. 443 p.

Myrick, C.A. and J.J. Cech, Jr. 2001. Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing on California's Central Valley Populations. Technical Publication 01-1. Sacramento, CA: Bay-Delta Modeling Forum.

Naiman, R.J., K.L. Fetherston, S.J. McKay, and J. Chen. 1998. Riparian Forests. Pages 289-323 in R.J. Naiman and R.E. Bilby (eds). River Ecology and Management: Lessons from the Pacific Coastal Ecoregion. Springer, New York.

Narum, S.R., Di Genova, A., Micheletti, S.J., and Maass, A. 2018. Genomic Variation Underlying Complex Life-History Traits Revealed by Genome Sequencing in Chinook Salmon. Proceedings of the Royal Society B: Biological Sciences 285(1883):20180935.

National Marine Fisheries Service (NMFS). 1998a. Endangered and Threatened Species: Proposed Endangered Status for Two Chinook Salmon ESUs and Proposed Threatened Status for Five Chinook Salmon ESUs; Proposed Redefinition, Threatened Status, and Revision of Critical Habitat for One Chinook Salmon ESU; Proposed Designation of Chinook Salmon Critical Habitat in California, Oregon, Washington, Idaho. Federal Register Vol. 63, No. 45, March 9, 1998.

National Marine Fisheries Service (NMFS). 1998b. Status Review Update for West Coast Chinook Salmon (*Oncorhynchus tshawytscha*) from Puget Sound, Lower Columbia River, Upper Willamette River, and Upper Columbia River Spring-Run ESUs. Prepared by the West Coast Chinook Salmon Biological Review Team.

National Marine Fisheries Service (NMFS). 1998c. Factors Contributing to the Decline of Chinook Salmon: An Addendum to the 1996 West Coast Steelhead Factors For Decline Report. National Oceanic and Atmospheric Administration. Protected Resources Division, National Marine Fisheries Service. Portland, OR. 74 pp.

National Marine Fisheries Service (NMFS). 2011. Endangered and Threatened Species: Threatened Status for the Oregon Coast Coho Salmon Evolutionarily Significant Unit. Federal Register, Vol. 76, No. 118, June 20, 2011.

National Marine Fisheries Service and U.S. Fish and Wildlife Service (NMFS and USFWS). 2006. Endangered Species Act Section 7 Consultation Biological Opinion and Section 10 Statement of Findings and Magnuson-Stevens Fishery and Conservation and Management Act Essential Fish Habitat Consultation for Washington State Forest Habitat Conservation Plan. National Marine Fisheries Services, Northwest Region.

National Research Council (NRC). 2004. Endangered and Threatened Fishes in the Klamath River Basin: Causes of Decline and Strategies for Recovery. National Academy of Sciences. Washington DC: The National Academies Press. 397 pp.

Nehlsen, W., J.E. Williams and J.A. Lichatowich. 1991. Pacific Salmon At the Crossroads: Stocks at Risk from California, Oregon, Idaho and Washington. Fisheries 16(2): 4-21.

Nicholas, J.W., and D.G. Hankin. 1989. Chinook Salmon Populations in Oregon Coastal River Basins: Description of Life Histories and Assessment of Recent Trends in Run Strengths. Salem, OR: Oregon Department of Fish and Wildlife, Fish. Div. Info. Rep., No. 88-1. p. 359.

North Coast Regional Water Quality Control Board (NCRWQCB). 2010. Klamath River Total Maximum Daily Loads (TMDLs) Addressing Temperature, Dissolved Oxygen, Nutrient, and Microcystin Impairments In California: Final Staff Report.

Northwest Fisheries Science Center (NWFSC). 2015. Status Review Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Pacific Northwest.

Northwest Hydraulic Consultants Inc. (NHC). 2020. Addendum to the Chehalis Watershed Management Plan -- Chehalis Watershed (WRIA 22/23) Response to 2018 Streamflow Restoration Law. Prepared for Chehalis Basin Partnership with assistance from Ecology Grant No. GHCoPS-00021. November, 2020.

Northwest Indian Fisheries Commission Member Tribes (NIFC). 2020. 2020 State of Our Watersheds: A Report by the Treaty Tribes in Western Washington.

Ohlberger, J. T.W. Buehrens, S.J. Brenkman, P. Crain, T.P. Quinn, R. Hilborn. 2018. Effects of Past and Projected River Discharge Variability on Freshwater Production in Anadromous Fish. Freshwater Biology 63: 331-340.

Oliver ECJ, Burrows MT, Donat MG, Sen Gupta A, Alexander LV, Perkins-Kirkpatrick SE, Benthuysen JA, Hobday AJ, Holbrook NJ, Moore PJ, Thomsen MS, Wernberg T and Smale DA. 2019. Projected Marine Heatwaves in the 21st Century and the Potential for Ecological Impact. Front. Mar. Sci. 6:734

Pacific Fisheries Management Council (PFMC). 1978. Fishery Management Plan for Commercial and Recreational Salmon Fisheries Off the Coasts of Washington, Oregon, and California Commencing in 1978. Pacific Fisheries Management Council, March 1978, Portland, OR.

Pacific Fishery Management Council (PFMC). 2018. Review of 2017 Ocean Salmon Fisheries: Stock Assessment and Fishery Evaluation Document for the Pacific Coast Salmon Fishery Management Plan. Pacific Fishery Management Council, Portland, OR.

Pearse, D.E., Garza J.C., Myers J., Spence B. 2019. Northern California Steelhead DPS Configuration Review-Panel Report.

Peery, C.A., Kavanagh, K.L., and Scott, J.M. 2003. Pacific Salmon: Setting Ecologically Defensible Recovery Goals. BioScience 53(7):622-623.

Perry, T.D. and J.A. Jones. 2017. Summer Streamflow Deficits from Regenerating Douglas-Fir Forest in the Pacific Northwest, USA. Ecohydrology 10(2), e1790

Peterson, R. L., R. A. Clark, and D. F. Evenson. 2016. Does the Queets Exploitation Rate Indicator Stock Represent the Distribution of Fishery Impacts of Washington Coast Chinook Salmon Stocks in Pacific Salmon Treaty Fisheries? Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J.2016-06, Juneau

Phinney, L.A., and P. Bucknell. 1975. A Catalog of Washington Streams and Salmon Utilization. Volume 2: Coastal region. Washington Department of Fisheries, Olympia, WA.

Piety, L.A., J.A. Bountry, T.J. Randle, E.W. Lyon. 2004. Summary Report for Geomorphic Assessment of Hoh River in Washington State: River Mile 17 to 40 Between Oxbow Canyon and Mount Tom Creek. US Department of Interior, Bureau of Reclamation, Denver, CO.

Pollock M.M., S. Baker, R. Bigley, W. Scarlett. 2004. Summer Stream Temperatures in the Olympic Experimental State Forest, Washington. Washington State Department of Natural Resources, Olympia, WA.

Primack, R.B. 2008. A Primer of Conservation Biology. No. QH75 P74 2000. Sunderland: Sinauer Associates.

Prince, D.J., S.M. O'Rourke, T.Q. Thompson, O.A. Ali, H.S. Lyman, I.K. Saglam, T.J. Hotaling, A.P. Spidle and M.R. Miller. 2017. The Evolutionary Basis of Premature Migration in Pacific Salmon Highlights the Utility of Genomics for Informing Conservation. Science Advances 3, August 16, 2017.

Quinault Indian Nation (QIN). 2000. Salmon River Watershed Analysis. Quinault Indian Nation Department of Natural Resources, Taholah, WA.

Quinault Indian Nation and U.S. Forest Service (QIN and USFS). 1999. Quinault River Watershed Analysis. Quinault Indian Nation, Taholah, WA.

Quinault Indian Nation (QIN). 2008. Salmon Habitat Restoration Plan; Upper Quinault River. QDNR, Department of Fisheries, Quinault Indian Nation, Taholah, Washington: Quinault Indian Nation, Department of Fisheries & Herrera Environmental Consultants, Inc., 2008. Taholah, WA.

Quinault Indian Nation Lead Entity (QINLE). 2011. WRIA 21 Queets/Quinault Salmon Habitat Recovery Strategy. Prepared by WRIA 21 lead entity. Tahola, Washington.

Quinn, T.P. 2018. The Behavior and Ecology of Pacific Salmon and Trout, second edition. University of Washington Press in association with American Fisheries Society, 520 pp.

Quinn, T.P. and D.J. Adams. 1996. Environmental Changes Affecting the Migratory Timing of American Shad and Sockeye Salmon. Ecology 77: 1151– 1162.

Quinn, T.P., McGinnity P., and Reed T.E. 2016. The Paradox of “Premature Migration” by Adult Anadromous Salmonid Fishes: Patterns and Hypotheses. Can J Fish Aquat Sci. 73:1015–1030.

Reeves, G.H., D.H. Olson, S.M Wondzell, PA. Bisson, S. Gordon, S.A. Miller, J.W. Long, and M.J. Furniss. 2006. Chapter 7: The Aquatic Conservation Strategy of the Northwest Forest Plan – A Review of the Relevant Science After 23 Years. In Spies, T.A..; Stine. P.A.; Gravenmier R.; Long, J.W.; Reilly, M.J., tech cords. 2018. Synthesis of Science to Inform Land Management Within the Northwest Forest Plan area. Gen. Tech. Rep. PNW-GTR-966. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 461-624.

Reisenbichler, R.R. 1987. Basis for Managing the Harvest of Chinook Salmon. North American Journal of Fisheries Management 7(4):589-591.

Richter, A. and Kolmes, S.A., 2005. Maximum Temperature Limits for Chinook, Coho, and Chum Salmon, and Steelhead Trout in the Pacific Northwest. Reviews in Fisheries Science, 13(1), pp.23-49.

Ricker, W.E. 1973. Two Mechanisms That Make It Impossible to Maintain Peak-Period Yields from Stocks of Pacific Salmon and Other Fishes. Journal of the Fisheries Board of Canada 30(9):1275-1286.

Ricker, W.E. 1981. Changes in the average size and average age of Pacific salmon. Canadian Journal of Fisheries and Aquatic Sciences 38:1636–1656.

Riddell, B.E., R.D. Brodeur, A.V. Bugaev, P. Moran, J.M. Murphy, J.A. Orsi, M. Trudel, L.A. Weitkamp, B.K. Wells, and A.C. Wertheimer. 2018. Ocean Ecology of Chinook Salmon. Pages 555-696 *in* R.J. Beamish (ed.) Ocean Ecology of Pacific Salmon and Trout. American Fisheries Society, Bethesda, MD

Riedel, J.L., Wilson, S., Baccus, W. Larrabee, M., Fudge, T.J., and A. Fountain. 2015. Glacier Status and Contribution to Streamflow in the Olympic Mountains, Washington, USA. Journal of Glaciology (61)225: 8-16.

Ronne L., N. VanBuskirk, and M. Litz. 2020. Spawner Abundance and Distribution of Salmon and Steelhead in the Upper Chehalis River, 2019 and Synthesis of 2013-2019. FPT 20-06 Washington Department of Fish and Wildlife, Olympia, WA.

Ruiz-Villanueva, V., H. Piégay, A.A. Gurnell, R.A. Marston, M. Stoffel. 2016. Recent Advances Quantifying the Large Wood Dynamics in River Basins: New Methods and Remaining Challenges. Reviews of Geophysics 54. DOI:10.1002/2015RG000514.

Ryan, J. 2021. Northwest Glaciers are Melting. What That Means to Indigenous 'Salmon People.' KUOW and NPR news. November 6, 2021. https://www.opb.org/article/2021/11/15/northwest-glaciers-melting-indigenous-salmon-people/

Sandell, T., J. Fletcher, A. McAninch, and M. Wait, 2015. Grays Harbor Estuary Salmonid Conservation and Restoration Plan. Available from: http://wildfishconservancy.org/projects/graysharbor-juvenile-salmon-fish-communitystudy/WFC2015GraysHarborEstuaryconservationplan.final.pdf.

Satterthwaite, W.H. and S.M. Carlson. 2015. Weakening Portfolio Effect Strength in a Hatchery-Supplemented Chinook Salmon Population Complex. Canadian Journal of Fisheries and Aquatic Sciences 72(12):1860-1875.

Sauter, S.T., Crawshaw, L.I., and Maule, A.G. 2001. Behavioral Thermoregulation by Juvenile Spring and Fall Chinook Salmon, *Oncorhynchus tshawytscha*, During Smoltification. Environmental Biology of Fishes 61(3):295-304.

Scheuerell M.D., P.S. Levin, R.W. Zabel, J.G. Williams, and B.L. Sanderson. 2005. A New Perspective on the Importance of Marine-Derived Nutrients to Threatened Stocks of Pacific Salmon (*Oncorhynchus* spp.). Canadian Journal of Fisheries and Aquatic Sciences 62:961–964.

Schindler, D.E., Hilborn, R., Chasco, B., Boatright, C.P., Quinn, T.P., Rogers, L.A., and Webster, M.S. 2010. Population Diversity and the Portfolio Effect in an Exploited Species. Nature 465(7298):609.

Sedell, J. R., and J. L. Froggatt. 1984. The importance of stream-side forests to large rivers: the isolation of the Willamette River, Oregon, USA from its floodplain by snagging and stream-side forest removal. Internationale Vereinigung fur theoretische und angewandte Limnologie, Verhandlungen 1:1828-1834.

Seiler, D. 1989. Differential Survival of Grays Harbor Basin Salmonids: Water Quality Implications. Pages 123-135 in C.D. Levings, L.B. Holtby, and M.A. Henderson (eds.] Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks. Canadian Special Publication Fisheries and Aquatic Sciences 105.

Shared Strategy Development Committee (SSDC). 2007. Puget Sound Salmon Recovery Plan. Vol. 1. Plan adopted by the National Marine Fisheries Service (NMFS) January 19, 2007.

Sharma, R. 2009. Survival, Maturation, Ocean Distribution and Recruitment of Pacific Northwest Chinook Salmon (*Oncorhynchus tshawytscha*) in Relation to Environmental Factors, and implications for Management. Doctoral dissertation. University of Washington, Seattle, WA

Sharma, R. and M. Liermann. 2010. Using Hierarchical Models to Estimate Effects of Ocean Anomalies on North-West Pacific Chinook Salmon *Oncorhynchus tshawytscha* Recruitment. Journal of Fish Biology 77(8):1948-1963.

Simenstad, C.A., and D.M Eggers. 1981. Juvenile Salmonid and Baitfish Distribution, Abundance, and Prey Resources in Selected Areas of Grays Harbor, Washington. Final report to U.S. Army Corps of Engineers, Seattle District, August 1981. Seattle, WA.

Smith, C.J. 2000. Salmon and Steelhead Habitat Limiting Factors in the North Washington Coastal Streams of WRIA 20. Washington State Conservation Commission. Lacey, Washington, DOI: https://rco.wa.gov/wp-content/uploads/2019/10/GSRO-LimitingFactorReport.pdf

Smith, C.J. 2005. Salmon Habitat Limiting Factors in Washington State. Washington State Conservation Commission. Olympia, WA.

Smith, C., and M. Wenger, 2001. Salmon and Steelhead Limiting Factors, Chehalis Basin and Nearby Drainages, Water Resource Inventory Areas 22 and 23. Washington State Conservation Commission. 2001.

Smith, C.J, and J. Caldwell. 2001. Salmon and Steelhead Habitat Limiting Factors in the Washington Coastal Streams of WRIA 21. Washington State Conservation Commission, 2001.

Spanjer, A.R., A.S. Gendaszek, E.J. Wulfkuhle, R.W. Black, and K.L. Jaeger. 2022. Assessing Climate Change Impacts on Pacific Salmon and Trout Using Bioenergetics and Spatiotemporal Explicit River Temperature Predictions Under Varying Riparian Conditions. PLoS ONE 17(5): e0266871. https://doi.org/10.1371/journal.pone.0266871

Stiefel, O. 2013. All carrot and no stick: why Washington's Clean Water Act assurances violate state and federal water quality laws. Washington Law Review, vol. 88, no. 2, June 2013, pp. 683

Storm, J.M., D. Chance, J. Harp, K. Harp, L. Lestelle, S.C. Sotomish, and L. Workman. 1990. Land of the Quinault. Quinault Indian Nation, Taholah, WA.

Stout, H. A., P. W. Lawson, D. Bottom, T. Cooney, M. Ford. C. Jordon, R. Kope, L. Kruzic, G. Pess, G. Reeves, M. Sheuerell, T. Wainwright, R. Waples, L. Weitkamp, J. Williams, and T. Williams. 2012. Scientific Conclusions of the Status Review for Oregon Coast Coho Salmon (*Oncorhynchus kisutch*). Northwest Fisheries Science Center, Seattle, WA.

Suttle, K.B., Power, M.E., Levine, J.M. and McNeely, C., 2004. How Fine Sediment in Riverbeds Impairs Growth and Survival of Juvenile Salmonids. Ecological Applications, 14(4), pp.969-974.

Sutton, R.J., Deas, M.L., Tanaka, S.K., Soto, T., and Corum, R.A. 2007. Salmonid Observations at a Klamath River Thermal Refuge Under Various Hydrological and Meteorological Conditions. River Research and Application 23(7):775-785.

Sykes, G.E., Johnson, C.J., and Shrimpton, J.M. 2009. Temperature and Flow Effects on Migration Timing of Chinook Salmon Smolts. Transactions of the American Fisheries Society 138(6), 1252-1265.

Teichert M.A.K., Foldvik A., Forseth T., Ugedal O., Einum S., Finstad A.G., Hedger R.D., and Bellier E. 2011. Effects of Spawning Distribution on Juvenile Atlantic Salmon (*Salmo salar*) Density and Growth. Canadian Journal of Fisheries and Aquatic Science 68(1): 43–50.

Tetra Tech/KCM, Inc. 2003. 2003 Chehalis Basin Water Quantity Evaluation. Prepared for Chehalis Basin Partnership.

Thomas, J.W.; Raphael, M.G.; Anthony, R.G.; Forsman, E.D.; Gunderson, A.G.; Holthausen, R.S.; Marcot, B.G.; Reeves, G.H.; Sedell, J.R.; Solis, D.M. 1993. Viability assessments and management considerations for species associated with late successional and old-growth forests of the Pacific Northwest: the report of the Scientific Analysis Team. Portland, OR: U.S. Department of Agriculture, National Forest System, Forest Service Research. 530 p.

Thompson, T.Q., Bellinger M.R., O'Rourke S.M., Prince D.J., Stevenson A.E., Rodrigues A.T., Sloat M.R., Speller C.F., Yang D.Y., Butler V.L., et al. 2019a. Anthropogenic Habitat Alteration Leads to Rapid Loss of Adaptive Variation and Restoration Potential in Wild Salmon Populations. Proc Natl Acad Sci USA. 116:177–186. https://salmon-net.org/wp-content/uploads/2019/08/Thompson_etal_2018_slides.pdf

Thompson, T.Q., O'Rourke S.M., Brown S.K., Seamons T., Zimmerman M., and Miller M.R. 2019b. Run-Type Genetic Markers and Genomic Data Provide Insight for Monitoring Spring-Run Chinook Salmon in the Chehalis Basin, WDFW contract #18-11697. Final report submitted to Washington Department of Fish and Wildlife. p. 26. https://chehalisbasinstrategy.com/wp-content/uploads/2020/01/10_Run-Type-Genetic-Markers-and-Genomic-Data-Provide-Insight-for-Monitoring-Spring-Chinook.pdf

Thompson, N.F., Anderson E.C., Clemento A.J., Campbell M.A., Pearse D.E., Hearsey J.W., Kinziger A.P., and Garza J.C. 2020. A Complex Phenotype in Salmon Controlled by a Simple Change in Migratory Timing. Science. 370:609–613.

Tiffan, K.T, J.M. Erhardt, R.J. Hemingway, B.K. Bickford, and T.N. Rhodes. 2020. Impact of Smallmouth Bass Predation on Subyearling Fall Chinook Salmon Over a Broad River Continuum. Environmental Biology of Fishes. 103(10): 1231–1246. http://doi: 10.1007/s10641-020-01016-0.

Tillotson, M.D., and T.P. Quinn. 2018. Selection on the Timing of Migration and Breeding: A Neglected Aspect of Fishing-Induced Evolution and Trait Change. Fish and Fisheries 19: 170–181. https://doi.org/10.1111/faf.12248

Tillotson, M.D., Arostegui M.C., Austin C.S., Lincoln A.E., Matsubu W., McElroy K.N., and Quinn T.P. 2021. Challenges in the Identification and Interpretation of Phenological Shifts: Anthropogenic Influences on Adult Migration Timing in Salmonids. Rev Fish Sci Aquac. 29:769–790.

Torgersen, C.E., Price, D.M., Li, H.W., and McIntosh, B.A. 1999. Multi-Scale Thermal Refugia and Stream Habitat Associations of Chinook Salmon in Northeastern Oregon. Ecological Applications 9: 301– 319.

Trihey and Associates, Inc. 1996. Instream Flow Requirements for Tribal Trust Species in the Klamath River. Prepared by Trihey and Associates, Inc., Concord, CA, for the Yurok Tribe, Eureka, CA. 43 pp.

Tschaplinski, P.J. and R.G. Pike. 2017. Carnation Creek Watershed Experiment—Long-Term Responses of Coho Salmon Populations to Historic Forest Practices. Ecohydrology 10:e1812

U.S. Army Corps of Engineers (USACOE). 2020. Draft Chehalis River Basin Flood Damage Reduction Project NEPA Environmental Impact Statement. U.S. Army Corps of Engineers, Seattle District, September 18, 2020. Seattle, WA.

U.S. Bureau of Reclamation (USBOR). 2005. Geomorphic Investigation of Quinault River, Washington: Lake Quinault to Confluence of East and North Fork Quinault. U.S. Department of Interior, Bureau of Reclamation, Technical Service Center, Denver, CO.

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management [USDA and USDI]. 1994. Environmental assessment for the implementation of interim strategies (PACFISH) for managing anadromous fish-producing watersheds in eastern Oregon and Washington, Idaho, and portions of California. Washington, DC.

U.S. Forest Service (USFS). 1990. Land and Resource Management Plan Olympic National Forest. U.S. Forest Service, Pacific Northwest Region, Olympia, WA.

U.S. Forest Service (USFS). 1995. Matheny Creek Watershed Analysis. Quinault Ranger District, Olympic National Forest, Lake Quinault, Washington.

U.S. Forest Service (USFS). 1997. Sams River Watershed Analysis. Quinault Ranger District, Olympic National Forest, Lake Quinault, Washington.

U.S. Fish and Wildlife Service (USFWS). 2020. Biological Opinion for Programmatic Forest Management Activities on the Olympic National Forest June 15, 2020 to June 15, 2030. USFW Reference: 13410-2009-F-0388-R001. Lacey, WA.

Von Schuckmann et al. 2020. Heat Stored in the Earth System: Where Does the Energy Go? Earth Syst. Sci. Data, 12, 2013–2041.

Wade, A.A., Beechie, T.J., Fleishman, E., Mantua, N.J., Wu, H., Kimball, J.S., Stoms, D.M., and J.A. Stanford. 2013. Steelhead Vulnerability to Climate Change in the Pacific Northwest. Journal of Applied Ecology 50 (5), 1093–1104. https://doi.org/10.1111/1365-2664.12137.

Walters, A.W., Bartz, K.K., and McClure, M.M. 2013. Interactive Effects of Water Diversion and Climate Change for Juvenile Chinook Salmon in the Lemhi River Basin (USA). Conservation Biology 27(6):1179-1189.

Walters, C.J. and S.J.D. Martell. 2004. Fisheries Ecology and Management. 448 p. Princeton University Press.

Waples, R.S. 1991. Pacific Salmon, *Oncorhynchus spp.*, and the Definition of “Species” Under the Endangered Species Act. Mar Fish Rev. 53:11–22.

Waples, R.S., Ford, M.J., Nichols, K., Kardos, M., Myers, J., Thompson, T.Q., Anderson, E.C., Koch, I.J., McKinney, G., Miller, M.R. and Naish, K., 2022. Implications of Large-Effect Loci for Conservation: A Review and Case Study with Pacific Salmon. Journal of Heredity.

Washington Coast Sustainable Salmon Partnership (WCSSP). 2013. Washington Coast Sustainable Salmon Plan.

Washington Department of Ecology (WDOE). 2016. Current Water Quality Assessment 303(d)/305(b) List. https://ecology.wa.gov/Water-Shorelines/Water-quality/Water-improvement/Assessment-of-state-waters-303d

Washington Department of Ecology (WDOE). 2020. State Environmental Policy Act Draft Environmental Impact Statement – Proposed Chehalis River Basin Flood Damage Reduction Project. Washington Department of Ecology, February 2020. Olympia, WA.

Washington Department of Fisheries (WDF). 1952. Coastal Investigation, 1952. Coastal Investigations Progress Reports, 1951-58. Research Division, Washington Department of Fisheries. Olympia, WA.

Washington Department of Fisheries (WDF). 1955. Coastal Investigation May through October, 1955. Coastal Investigations Progress Reports, 1951-58. Research Division, Washington Department of Fisheries. Olympia, WA.

Washington Department of Fisheries (WDF). 1958. Coastal Investigations Progress Reports, 1951-58. Research Division, Washington Department of Fisheries. Olympia, WA.

Washington Department of Fish and Wildlife (WDFW). 1992. Washington State Salmon and Steelhead Stock Inventory. Washington Department of Fisheries, Washington Department Of Wildlife, and Western Washington Treaty Indian Tribes.

Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes (WDFW and WWTIT). 1994. 1992 Washington State Salmon and Steelhead Stock Inventory – Appendix Two Coastal Stocks. Olympia, WA.

Washington Department of Natural Resources (WDNR). 1997. Final Habitat Conservation Plan. Washington State Department of Natural Resources. September 1997. Olympia, WA.

Washington Department of Natural Resources (WDNR). 2016. Olympic Experimental State Forest Habitat Conservation Planning (HCP) Unit Forest Land Plan. Washington Department of Natural Resources, Olympia, WA.

Washington State Department of Ecology (WSDE). 2020. State Environmental Policy Act Draft Environmental Impact Statement: Proposed Chehalis River Basin Flood Damage Reduction Project. Ecology Publication 20-06-002. February.

West, J.R. 1991. A Proposed Strategy to Recover Endemic Spring Run Chinook Salmon Population and Their Habitats in the Klamath River Basin. Report to the Forest Service, Pacific Southwest Region. 26 pp.

Weitkamp, L.A. 2010. Marine Distributions of Chinook Salmon from the West Coast of North America Determined by Coded Wire Tag Recoveries. Transactions of the American Fisheries Society, 139:1, 147-170.

Wendler, H.O., and G. Deschamps. 1955. Logging Dams on Coastal Washington Streams. Fisheries Research Papers. Washington Department of Fisheries. Vol 1, No. 3, Olympia, WA.

Weyerhaeuser. 1994. Chehalis Headwaters Watershed Analysis. Weyerhaeuser Co. Seattle, Washington.

Wilhere, G., and T. Quinn. 2018. How Wide is Wide Enough?: Science, Values, and Law in Riparian Habitat Conservation, 58 Nat. Resources J. 279.

Willis, S.C., Hess J.E., Fryer J.K., Whiteaker J.M., Brun C., Gerstenberger R., and Narum S.R. 2020. Steelhead (*Oncorhynchus mykiss*) Lineages and Sexes Show Variable Patterns of Association of Adult Migration Timing and Age-At-Maturity Traits With Two Genomic Regions. Evol Appl. 13:2836–2856.

Willis, S.C., Hess J.E., Fryer J.K., Whiteaker J.M., and Narum S.R. 2021. Genomic Region Associated With Run Timing Has Similar Haplotypes and Phenotypic Effects Across Three Lineages of Chinook Salmon. Evol Appl. 14:2273–2285.

Winkowski, J., and M. Zimmerman. 2020. Chehalis Thermalscape and Thermal Summer Rearing Habitat. Presentation to the ASRP Science Symposium, January 7, 2020, Centralia, WA. https://www.chehalisbasinstrategy.com/wp-content/uploads/2020/01/4_Chehalis-Thermalscape-and-Optimal-Summer-Rearing-Habitat-Modeling.pdf

Wood, R.L. 1976. Men, Mules, and Mountains. The Mountaineers, Seattle, WA.

Wood, W.A. 1984. Trends in Historic Abundance and Present Status of Natural Stocks of North Coastal Washington Coho and Chinook Salmon. Pages 193-204 in J.M. Walton and D.B. Houston, editors. Olympic Wild Fish Conference. Peninsula College, Port Angeles, WA.

WRIA 21 Lead Entity. 2011. WRIA 21 Queets/Quinault Salmon Habitat Recovery Strategy. Prepared by the WRIA 21 Lead Entity. June 2011.

Wray, J.C. 1997. Olympic National Park Ethnographic Overview and Assessment. Olympic National Park. Port Angeles, WA. 252 p.

Yoder, J., C. Raymond, R. Basu, S. Deol, A. Fremier, K. Garcia, G. Mauger, J. Padowski, M. Rogers, and A. Stahl. 2022. Climate Change and Stream Flow: Barriers and Opportunities. Preliminary project report to the Washington State Department of Ecology.

Zabel, R.W., and J.G. Williams. 2002. Selective Mortality in Chinook Salmon: What is the Role of Human Disturbance? Ecological Applications 12(1):173–183.

Zimmerman, M. 2017. Ongoing Studies That Address Status of Spring Chinook Salmon in the Chehalis River. Memorandum to the Aquatic Species Restoration Plan Steering Committee, May 31, 2017.

Zwieniecki, M.A. and M. Newton. 1996. Seasonal Pattern of Water Depletion from Soil–Rock Profiles in a Mediterranean Climate in Southwestern Oregon. Canadian Journal of Forest Research 26(8):1346-1352