STATE OF CALIFORNIA
NATURAL RESOURCES AGENCY
DEPARTMENT OF FISH AND WILDLIFE

REPORT TO THE FISH AND GAME COMMISSION

California Endangered Species Act Status Review for Upper Klamath and Trinity Rivers Spring Chinook Salmon (*Oncorhynchus tshawytscha*)

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Glossary and Acronyms

Allozymes: Allelic variants of enzymes (proteins) encoded by structural genes used as markers in (especially older) population genetics studies.

Adaptive trait: A heritable genetic trait directly associated with the ability of an organism to maximize its survival and/or reproductive success.

Adipose fin-clip: Adipose fin removed on some or all hatchery-origin fish to indicate that they were produced in a hatchery. Fish with an adipose fin-clip may or may not also contain a coded wire tag.

Alleles: Alternative forms of a gene that arise by mutation and are found at the same place on a chromosome. Salmon are diploid organisms that possess two alleles for each gene, derived from each parent.

Alevin: An early life stage in salmonids that occurs immediately after hatching, also called "yolk-sac larvae." Alevin retain a yolk-sac that they use for nourishment and remain hidden in the gravel until they grow into fry.

Assortative mating: A mating pattern and form of sexual selection in which individuals with similar phenotypes mate with one another more frequently than expected by chance.

CDFW: California Department of Fish and Wildlife. Also "the Department." Previously named California Department of Fish and Game.

Commission: The California Fish and Game Commission.

CESA: California Endangered Species Act

Climate change: A change in global or regional climate patterns. In particular, a change apparent from the mid to late 20th century onwards attributed largely to increased levels of atmospheric carbon dioxide produced by use of fossil fuels.

Cohort replacement rate: A parameter that compares the number of spawning fish in the current year to the number of spawning fish one generation previous. Used to estimate whether a population is increasing, decreasing, or not changing in size over generational time.

CWT: Coded wire-tag. A (usually) numbered, very small wire tag inserted into the rostrum of some hatchery-origin fish. Fish with a coded wire-tag are usually identifiable by an external mark, typically an adipose fin-clip.

DNA: Deoxyribonucleic acid; Carrier of genetic information from one generation to the next in most organisms.

DPS: Distinct Population Segment. Under the federal ESA, the smallest division of a taxonomic species permitted to be protected under the U.S. Endangered Species Act. For Pacific salmon the DPS is synonymous with Evolutionarily Significant Unit.

Ecotype: A variant group that displays a distinct set of characters, but for which the phenotypic differences are too few or too subtle to warrant it being classified as a subspecies. Although ecotypes exhibit phenotypic differences (e.g., in morphology or physiology) stemming from environmental heterogeneity, they are capable of interbreeding with other geographically adjacent ecotypes.

Effective population size: Abbreviated N_e. The number of individuals in an idealized population that experience the same amount of drift as the population under consideration, where an idealized population has equal sex ratio, constant population size, and no variance in reproductive success.

Endangered species: Under the California Endangered Species Act, a native species or subspecies of a bird, mammal, fish, amphibian, reptile, or plant which is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease" (California Fish & G. Code §2062).

ENSO: El Niño Southern Oscillation. The interaction between the atmosphere and ocean in the tropical Pacific that results in periodic variation between below-normal and above-normal sea surface temperatures and dry and wet conditions over time.

ESA: United States Endangered Species Act.

ESU: Evolutionarily Significant Unit. The distinct unit of a biological species that defines a salmon "species" under the ESA of the United States. An ESU is a group of organisms (a population or group of populations) that (1) is substantially reproductively isolated from other conspecific populations, and (2) represents an important component in the evolutionary legacy of the species. In Pacific salmon, ESUs are the level at which endangered species management actions are directed.

Extinction: The cessation of existence, or the process leading to the cessation of existence, of a species or other taxon. The moment of extinction is generally considered to be the death of the last individual of that species or taxon, although the capacity to breed and recover may have been lost before this point.

Extirpation: Also called “local extinction.” The cessation of existence of a species or other taxon in a defined geographic area, though the species or taxon still exists elsewhere.

FMP: Fishery Management Plan. A monitoring and management plan required under the federal ESA for fisheries that affect listed stocks.

Fpp: Fish per pound. Used by hatcheries to estimate fish size. A sample of fish are counted, and the number divided by their weight in pounds.

Fry: The life stage of salmonids that occurs when alevin absorb the yolk-sac, emerge from the gravel, and begin to feed on external food items.

Gene: Traditionally defined as a sequence of nucleotides in DNA or RNA (ribonucleic acid) that encodes the synthesis of a gene product, either RNA or protein. Genes are more generally defined as locatable regions of genomic sequence, corresponding to a unit of inheritance, which is associated with regulatory regions, transcribed regions, and/or other functional sequence regions.

Gene association: When one or more genotypes within a population co-occur with a phenotypic trait more often than would be expected by chance occurrence.

Genetic diversity: The total number and type of characteristics in the genetic makeup of a species or other taxonomic or non-taxonomic group. Genetic diversity is distinguished from genetic variation, the tendency of genetic characteristics to differ.

Genetic drift: Random changes in allele frequencies from generation to generation in finite populations. Genetic drift is an especially important determinant of genetic diversity in small populations.

Genomics: An interdisciplinary field of biology and biotechnology that applies genetic and molecular biology techniques to the study of structure, function, evolution, mapping, and editing of genomes. A genome is an organism's complete set of DNA, including all its genes.

Geometric mean: A special type of average calculated by multiplying values and then taking the n^{th} root of the product. Characterizes central tendency in a way that minimizes the effect of outliers in widely varying data sets. (See text for calculations.)

Grilse: A salmon that has returned to spawn after only one winter at sea.

***GREB1L*:** A gene region on chromosome 28 in Chinook Salmon and Steelhead associated with early adult migration behavior. Also known as “*GREB1*-like retinoic acid receptor coactivator.”

Haplotype: A set of DNA variations (polymorphisms) that tend to be inherited together. A haplotype can refer to a combination of alleles or to a set of single nucleotide polymorphisms (SNPs) found on the same chromosome.

Hatchery-origin: Abbreviated HO. Fish that were produced and raised in a hatchery for some portion of their life cycle. (See Natural-origin.)

Heterozygous: Refers to the condition of having inherited different forms (alleles) of a gene from each parent. (See Homozygous.)

Homozygous: Refers to the condition of having inherited identical forms (alleles) of a gene from each parent. (See Heterozygous.)

Inbreeding depression: A reduction in fitness occurring because of mating among closely related individuals.

Introgression: Gene flow from one species or defined genetic group into the gene pool of another by the repeated backcrossing of hybrids with one or both of its parent “species.”

IUCN: International Union for the Conservation of Nature. Founded in 1948, the world’s oldest and largest global environmental organization.

Jack: A salmonid life-history strategy in which a proportion of males mature and return to freshwater after only one summer at sea. Chinook salmon jacks are typically 2 years old.

Kype: In many salmonids, such as Chinook Salmon, the hooked extension of the jaw that develops in males prior to reproduction. This secondary sexual characteristic is believed to help establish dominance hierarchies and access to spawning opportunities.

Microsatellite DNA: Short, tandemly repeated (e.g., di-, tri-, or tetranucleotide) segments of noncoding DNA scattered throughout the genome between and/or within genes. Often used as genetic markers because of their naturally occurring high variability in repeat number between individuals due to their high mutation rate.

Monophyletic group: Also called a clade. A group of organisms that consists of all the descendants of a common ancestor, or more precisely, of an ancestral population. (See Polyphyletic.)

Natural-origin: Abbreviated NO. Fish that were produced and raised in the wild without human assistance. (See Hatchery-origin.) Includes offspring of hatchery-origin fish that spawned in the wild.

NMFS: National Marine Fisheries Service, also known as NOAA Fisheries. The primary federal fisheries agency for anadromous salmonids.

Parr: The freshwater life stage of salmonids, prior to seaward migration. Parr are usually juveniles, although a small percentage of parr in some species develop mature testes. Identified by characteristic parr marks along the sides of the body.

PDO: Pacific Decadal Oscillation. A recurring pattern of ocean-atmosphere climate variability centered over the mid-latitude Pacific basin. The PDO is characterized as warm or cool surface waters in the Pacific Ocean north of 20°N latitude.

PFMC: Pacific Fishery Management Council. The body that regulates commercial and recreational fishing in non-state ocean waters of the Pacific Ocean.

pHOS; Proportion of hatchery-origin spawning fish. The annual proportion of hatchery-origin fish that spawn in the wild.

PNI: Proportionate natural influence. A measure of the influence of hatcheries as a selective factor driving evolution in a combined hatchery and natural spawning system. PNI≥0.5 is desirable for most integrated systems, except for conservation programs that target PNI≥0.67. (See text for calculations.)

pNOB: Proportion of natural-origin broodstock. The annual proportion of natural-origin fish used as Broodstock in a hatchery program.

Polyphyletic group: A group of organisms that have been grouped together but do not share an immediate common ancestor. (See Monophyletic.)

Population: Organisms of the same species that live in the same place at the same time, with the capability of successfully interbreeding. Populations are sufficiently reproductively isolated to have their own distinct population dynamic trajectories.

Population component: Term used in this document to mean the members of a given ecotype that live in the same geographic area.

Population genetics: A field of biology that studies the genetic composition of biological populations, and the changes in genetic composition that result from the operation of various factors including genetic drift and natural selection.

Rkm: River kilometer. A measure of distance in kilometers along a river from its mouth. River kilometer numbers begin at zero and increase further upstream.

RM: River mile. A measure of distance in miles along a river from its mouth. River mile numbers begin at zero and increase further upstream.

ROCK1**:** A gene region on chromosome 28 in Chinook Salmon and Steelhead associated with early adult migration behavior. Also known as "Rho-associated coiled-coil-containing protein kinase 1."

SNP: Single nucleotide polymorphism. DNA sequence variations that occur when a single nucleotide (adenine, thymine, cytosine, or guanine) in a sequence is altered.

Salmonid: Members of the ray-finned fish family Salmonidae which contains salmon, trout, chars, freshwater whitefishes, and graylings.

Semelparity: A reproductive strategy in which organisms reproduce one time before dying (contrast to *Iteroparity*, in which organisms reproduce multiple times during their lifetime).

Smolt: The seaward migratory phase of salmon. While still in fresh water, fish undergoing smoltification experience a host of physiological, morphological, and behavioral changes that prepare them for migration to and entrance into salt water.

Species of Special Concern: Any California species, subspecies, or other taxon that has been placed on the California list of Species of Special Concern.

Straying: Return of salmonid spawning fish to a location other than the stream in which their parents spawned. Also used to refer specifically to hatchery-origin fish that return to natural spawning areas instead of their hatchery/ stream of origin.

Threatened species: A threatened species under CESA is a native species or subspecies that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by the CESA (Fish and Game Code, § 2067). (See Endangered Species.)

USBR: US Bureau of Reclamation

USFS: US Forest Service

USFWS: US Fish and Wildlife Service.

Viable population size: Number of individuals required for a population to persist for a specified time (usually 100 years) into the future.

Volitional release: A hatchery-origin juvenile release strategy that allows juveniles to move directly from hatchery to river as they become physiologically ready to migrate. Contrast with non-volitional release in which hatchery-origin juveniles are released on a given date regardless of physiological readiness.

A note on scientific and common names

Scientific and common names for fish used throughout this report conform to the standards of the American Fisheries Society. Common names for species are capitalized but families, group names, life history variants, ESUs, DPSs, and ecotypes are lower case (e.g., Pacific salmon, Chinook Salmon vs. fall Chinook Salmon; Rainbow Trout vs. steelhead). The same format is used for bird names, per the standards of the avian professional societies. Common names for other taxa are not capitalized, with the exception of proper nouns.

Executive Summary

Recommendation: Based on the best scientific information available, the Department has determined that the Upper Klamath-Trinity Rivers (UKTR) spring Chinook Salmon do not qualify as a separate evolutionarily significant unit (ESU). Although the spring ecotype is restricted in range and abundance in comparison to historic and recent time periods, the currently defined ESU (encompassing UKTR spring and fall Chinook Salmon) as a whole is not. Therefore, the Department recommendation is that the listing as requested by the petitioners is not warranted.

Reasons for recommendation: The Department finds that focus on the existing ESU for this listing determination is appropriate based on the petitioned action and is consistent with previous Pacific Salmon CESA-listings.

Population genetic studies, including recent genome-wide studies referenced in the petition, show evidence of past and ongoing reproductive exchange among UKTR spring and fall Chinook Salmon. UKTR spring Chinook are therefore not reproductively isolated from UKTR fall Chinook and share most of their evolutionary heritage. Only small genetic differences are observed between UKTR spring and fall Chinook Salmon.

The discovery of a strong association between run-timing and a specific genomic region referenced in the petition sheds light on the genetic underpinnings of run-timing diversity in salmon. However, at the whole genome level, genetic variation is organized by geography rather than by run-timing; UKTR spring and fall Chinook Salmon within a watershed are more closely related than spring Chinook Salmon in different watersheds or fall Chinook Salmon in different watersheds. Genome-wide data, focusing on groups of populations, are more reliable and appropriate for ESU delineation than variation at a single gene locus as suggested in the petition (Ford et al. 2020).

Use of this single genomic association for delineation of listing-units (ESUs) has potential to create inconsistent and biologically unsupportable ESU groupings. For example, mating among heterozygotes could result in both UKTR spring and fall Chinook Salmon in the same family.

Therefore, the Department finds that UKTR spring Chinook Salmon do not constitute their own ESU. Rather, they are best understood as an ecotype of the larger combined UKTR Chinook Salmon ESU. The presence of heterozygotes, fish with both spring and fall alleles at a gene region shown to be closely associated with run-timing, suggests that the spring ecotype could increase in frequency or be introduced from nearby sources when and if environmental conditions favoring the spring ecotype become available. However, because of the small number of UKTR spring Chinook Salmon currently found in the Klamath River, rapid recovery of spring returning fish will likely require active introduction of spring alleles from other places where UKTR spring Chinook Salmon are more abundant (e.g., the Trinity River). If conditions worsen, and in the absence of active measures to increase the number of spring alleles in the Klamath River, the spring allele is vulnerable to local extirpation there.

Range and Distribution: UKTR spring Chinook Salmon were more widely distributed in the basin historically than at present. It is generally thought that UKTR spring Chinook Salmon were the historically dominant ecotype. Although all areas in the basin are not currently surveyed, and small numbers return to other tributaries, UKTR spring Chinook Salmon are currently mainly found in three disparate spawning aggregations: Salmon River, South Fork Trinity River, and Upper Trinity River. UKTR fall Chinook Salmon are also found in these places as well as being widely distributed through other parts of the Klamath-Trinity watershed. Both UKTR spring and fall Chinook Salmon are limited in their upstream distribution by dams.

Status and Trend: Recent average (geometric mean, $\bar{G}$) annual abundance for UKTR spring Chinook Salmon spawners in the Salmon River (100s of fish), and especially in the South Fork Trinity River (10s of fish) are low. In contrast, UKTR spring Chinook Salmon in the Upper Trinity River persist at much higher annual average numbers (1,000s of fish, Figure ES-1). UKTR fall Chinook Salmon average abundance ($\bar{G}$) is lower than in the past, but recent estimates are still in the 1,000s of fish at six monitored locations (Figure ES-2). When UKTR spring and fall Chinook Salmon adult return numbers are combined, comprising both ecotypes over a larger number of surveyed sites, their averages ($\bar{G}$) are in the 10,000s of annual spawners (Figure ES-3). Similarly, the UKTR Chinook Salmon ESU (spring plus fall) overall average abundance ($\bar{G}$) is in the 10,000s annually, and is relatively stable over the monitoring period (Figure ES-4).

Although the trend in abundance of the spring ecotype is in decline (trend estimate <1) in at least two of the three monitored locations (the Salmon River and the South Fork Trinity River) in recent years, trend of the larger combined UKTR Chinook Salmon ESU is not (Figures ES-1, ES-2, ES-3, ES-4). Wide confidence intervals that include “no change” in abundance do not support many of the trend estimates in this and other trend analyses. Based on all available analyses from the Department, National Marine Fisheries Service, and other status reviews, the combined UKTR Chinook Salmon ESU is not in danger of immediate extinction over a 100-year time frame.

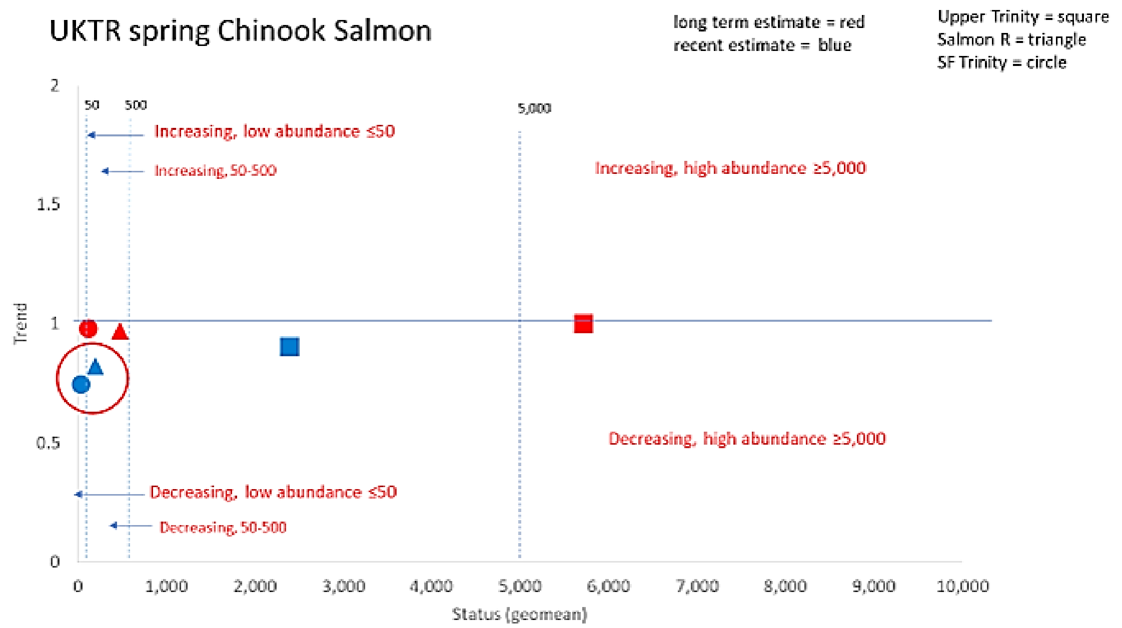


Figure ES-1. Quad plot of status and trend for UKTR spring Chinook Salmon population components over long-term and recent time periods. Only recent trends for South Fork Trinity River and Salmon River are significant for decline over the monitoring period (Red circled points). Isolines shown for geometric mean abundance of 50, 500, and 5,000.

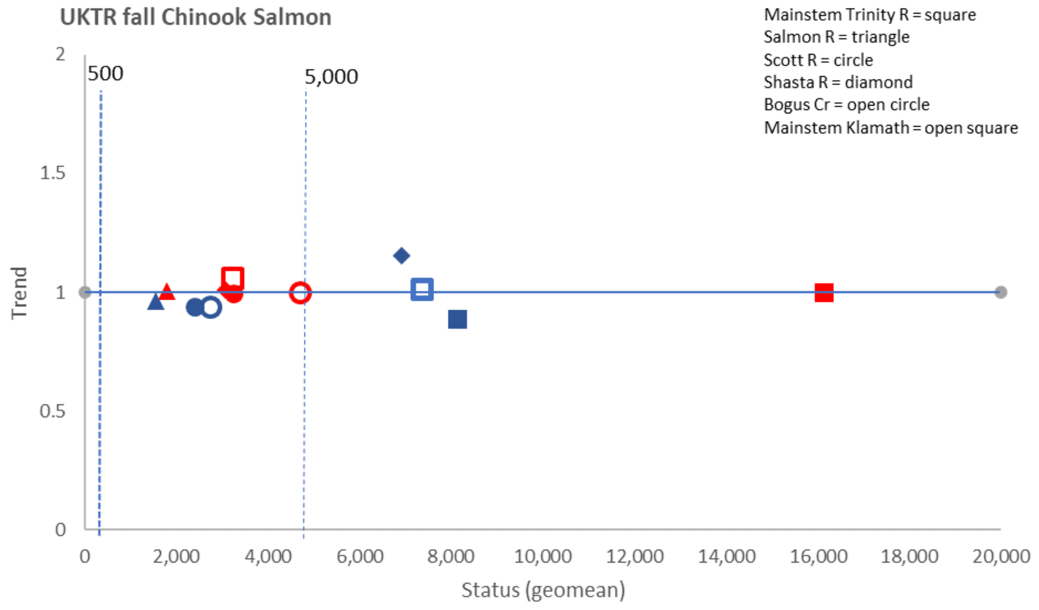


Figure ES-2. Quad plot of status and trend for UKTR fall Chinook Salmon population components over long-term and recent time periods. None of the trends are significant for change over the monitoring period. Isolines shown for geometric mean abundance of 500 and 5,000.

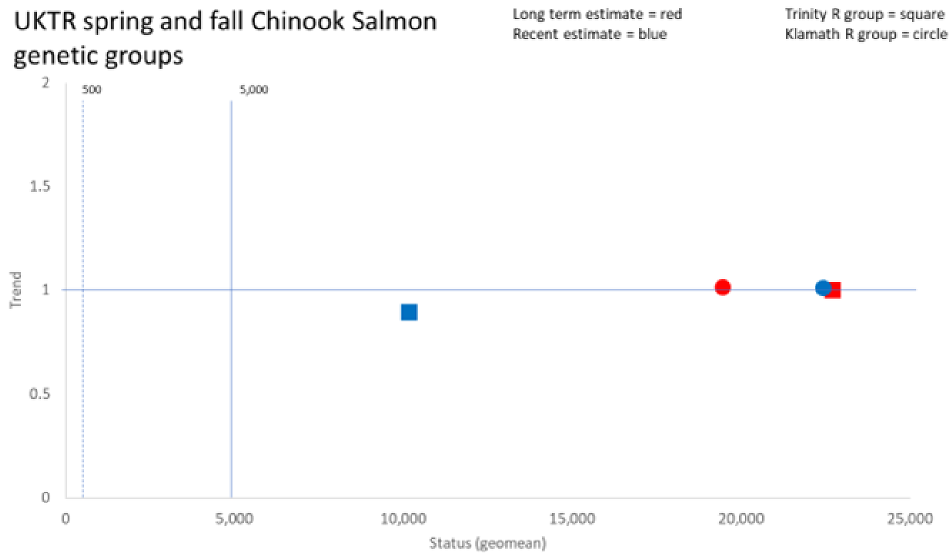


Figure ES-3. Quad plot of status and trend for UKTR Chinook Salmon genetic groups over long-term and recent time periods. None of the trends are significant for change over the monitoring period. Isolines shown for geometric mean abundance of 500 and 5,000.

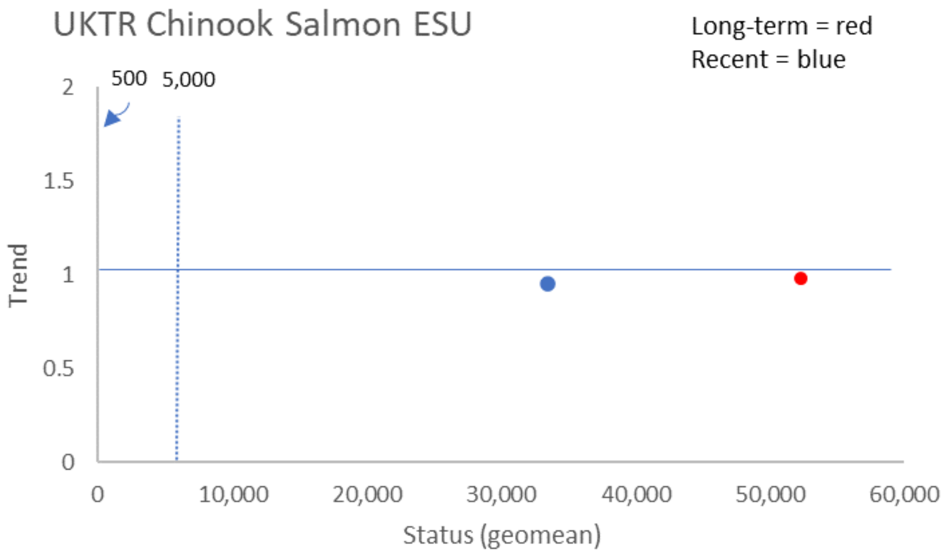


Figure ES-4. Quad plot of status and trend for UKTR Chinook Salmon ESU (spring + fall) over long-term and recent time periods. None of the trends are significant for change over the monitoring period. Isolines shown for geometric mean abundance of 500 (approximate) and 5,000.

Major listing factors: Iron Gate (IGH; Klamath) and Trinity River (TRH) Hatcheries produce large numbers of UKTR fall Chinook Salmon and TRH produces more modest numbers of UKTR spring Chinook Salmon every year. Likely due to consistent on-site releases, most hatchery influence is concentrated near the hatcheries with fewer hatchery strays in locations farther from the hatcheries. Because only TRH produces UKTR spring Chinook Salmon, spring-returning hatchery fish mostly impact the Upper Trinity River UKTR spring Chinook Salmon group, and to a lesser degree, the South Fork Trinity River group. Hatchery strays to the Salmon River and other parts of the Trinity River are uncommon. Rough estimates of Proportionate Natural Influence (PNI) for the Upper Trinity River UKTR spring Chinook Salmon group does not currently meet accepted conservation guidelines for protection of natural stocks. Based on this limited analysis, UKTR spring Chinook Salmon production at TRH could be negatively affecting long-term persistence prospects of naturally spawning Upper Trinity River Springs. However, natural-origin spawners are also supplemented by hatchery fish in this location adding to the group's relatively high abundance and low extinction risk. More data are necessary to be certain of the trade-offs between supplementation and long-term impacts.

Climate change projections for the Klamath Basin are for generally warmer and drier conditions than historically. Models project annual average temperature increase by about 1.1-2.0° C by mid-century, and 2.5-4.6° C by late century. In both the upper and lower Klamath basins, climate change will likely cause vegetation shifts toward those adapted to drier and warmer conditions. Other likely climate change effects include poorer water quality, changes in stream flow patterns, reduced snowpack and shorter melt season, additional fine sediment, algal blooms, and more frequent disease outbreaks. Temperature refugia will increase in importance as groundwater springs that provide it become scarcer.

Habitat alteration, especially dams, have negatively affected the UKTR Chinook Salmon ESU. The spring ecotype may be disproportionately affected by freshwater habitat degradation due to their extended freshwater residency for both adults and juveniles, and blockage from historical upstream spawning and rearing areas. Plans to remove four Klamath River dams may improve conditions generally for the UKTR Chinook Salmon ESU. However, it is unclear how dam removal would affect the UKTR spring Chinook Salmon ecotype directly.

Disease, especially in the Klamath River, is a major factor that affects both juvenile and adult UKTR Chinook Salmon. Current flow modifications are in place to mitigate disease impacts. The proposed removal of Klamath Dams may substantially reduce the incidence and severity of disease impacts.

Although environmental and anthropogenic factors likely limit productivity to some extent, the Department finds that the listing factors considered in this review do not threaten the ability of the UKTR Chinook Salmon ESU to survive and reproduce. Numbers of the combined spring and fall Chinook Salmon in this ESU remain robust and are similar over the last few decades, largely due to the abundance and wide distribution of the fall ecotype.

The Department believes that the degree and immediacy of threat for the combined UKTR Chinook Salmon ESU is low. However, immediate conservation actions are necessary for protection and enhancement of the UKTR spring Chinook salmon ecotype portion of the UKTR Chinook Salmon ESU.

Regardless of whether the Commission decides to list UKTR spring Chinook Salmon as a threatened or endangered species under CESA, the Department recommends the following management changes to support existing small and fragmented UKTR spring Chinook Salmon population components:

1. Investigate use of *GREB1L/ROCK1* genes for genetic stock identification in both ocean and inland fisheries. Collection and analysis of genetic data have high potential to provide information about abundance and ocean distribution of both natural- and hatchery-origin UKTR spring Chinook Salmon.
2. Implement monitoring of *GREB1L/ROCK1* genetic markers TRH Chinook salmon broodstock to verify the transition timing of UKTR spring and fall Chinook salmon.
3. Develop and implement a plan, within the framework of existing biological opinions, to add a conservation hatchery element to the UKTR spring Chinook Salmon program at TRH. This could either be a modification of the existing program to include conservation elements, or a separate smaller program focusing on conservation of the spring ecotype.
4. Implement CA HSRG (2012) recommendations for Trinity River Hatchery's UKTR spring and fall Chinook Salmon programs through the existing multiagency, multidisciplinary Hatchery Coordination Team.
5. Develop conservation hatchery strategies to increase the abundance of UKTR spring Chinook salmon in the Klamath River consistent with the goals of reintroduction plans.
6. Develop a monitoring plan for UKTR spring Chinook Salmon natural recovery in the Klamath River post dam removal.
7. Continue coordination with ODFW on a salmonid reintroduction plan, especially for UKTR spring Chinook Salmon, for the Klamath River post dam removal.
8. Consider implementing the California Coastal Monitoring Plan (CMP; Adams et al. 2011) for UKTR spring and fall Chinook Salmon in both the Klamath and Trinity rivers to obtain robust and unbiased estimates of both UKTR spring and fall Chinook Salmon status and trend throughout the basin.
9. Implement measures to improve the proportion of natural-origin fish used as broodstock in TRH's UKTR spring Chinook Salmon hatchery program and measures to reduce the proportion of hatchery-origin fish on natural spawning grounds in the Upper Trinity River such that the Proportionate Natural Influence (PNI) is at least 0.67 in accordance with CA HSRG (2012) guidelines.
10. Implement one of the following marking/tagging strategies for UKTR spring and fall Chinook Salmon at TRH: a) 100% CWT and adipose fin-flip, or b) the CA HSRG recommendation of 100% CWT and 25% adipose fin-clip. Alternatively, consider

implementation of 100% Parental Based Tagging (PBT) to replace or augment CWTs as a tagging method. Some studies (e.g., Anderson and Garza 2006, Steele et al. 2013) have shown that PBT may be more efficient and equally effective as 100% CWT.

11. Consider development of a mark-select fishery for in-river spring sport harvest in the Upper Trinity River to reduce hatchery-origin fish numbers on natural spawning grounds. This would likely require 100% adipose fin-clip marks for all TRH UKTR spring Chinook Salmon. Mark selective fisheries can have substantial negative impacts to natural-origin fish and should only be implemented with extreme caution.

We also recommend adoption and implementation of the following management recommendations proposed in Moyle et al. (2015):

12. Follow-through with plans to remove mainstem Klamath River dams;
13. Restore cold-water refugia on the Shasta River;
14. Continue to manage the Salmon River as a refuge for UKTR spring Chinook Salmon (and summer steelhead),
15. Develop and implement in-hatchery and in-stream monitoring to assess TRH hatchery impacts on natural stocks;
16. Accelerate habitat restoration to mitigate impacts from roads and logging; and
17. Revisit ocean and inland harvest to consider specific impacts to UKTR spring Chinook Salmon.

1. Introduction

1.1 Candidacy Evaluation

The California Endangered Species Act (CESA) sets forth a two-step process for listing a species as threatened or endangered. First, based on a petition for listing received from the public or another agency, the Commission determines whether to designate a species as a candidate for listing by determining whether the petition provides "sufficient information to indicate that the petitioned action may be warranted." (Fish & G. Code, § 2074.2(e)(2).) If the petition is accepted for consideration, the second step requires the California Department of Fish and Wildlife (the Department) to produce, within 12 months of the Commission's acceptance of the petition, a peer reviewed report based upon the best scientific information available that indicates whether the petitioned action is warranted. (Fish & G. Code, § 2074.6.) The Commission, based on that report and other information in the administrative record, then determines whether the petitioned action to list the species as threatened or endangered is warranted. (Fish & G. Code, § 2075.5.)

A petition to list a species under CESA must include "information regarding the population trend, range, distribution, abundance, and life history of a species, the factors affecting the ability of the population to survive and reproduce, the degree and immediacy of the threat, the impact of existing management efforts, suggestions for future management, and the availability and sources of information pertinent to the status of the species. The petition shall also include information regarding the kind of habitat necessary for species survival, a detailed distribution map, and other factors the petitioner deems relevant." (Fish & G. Code, § 2072.3; *see also* Cal. Code Regs., tit. 14, § 670.1, subd. (d)(1).) The species' range for the Department's petition evaluation and recommendation refers to the geographic range boundaries of the species in California. (*Cal. Forestry Assn. v. Cal. Fish and Game Com.* (2007) 156 Cal. App. 4th 1535, 1551.)

Within ten days of the receipt of a petition, the Commission must refer the petition to the Department for evaluation. (Fish & G. Code, § 2073.) The Commission must also publish notice of receipt of the petition in the California Regulatory Notice Register. (Fish & G. Code, § 2073.3.) Within 90 days of receipt of the petition, the Department must evaluate the petition on its face and in relation to other relevant information and submit to the Commission a written evaluation report with one of the following recommendations:

- Based upon the information contained in the petition, there is insufficient information to indicate that the petitioned action may be warranted, and the petition should be rejected; or
- Based upon the information contained in the petition, there is sufficient information to indicate that the petitioned action may be warranted, and the petition should be accepted, and the status of the species evaluated by the Department.

1.2 Petition History

On 23 July 2018, the Karuk Tribe and Salmon River Restoration Council submitted a petition to the Commission to classify the Upper Klamath-Trinity Rivers (UKTR) spring Chinook Salmon (*Oncorhynchus tshawytscha*) as a separate Evolutionarily Significant Unit (ESU) and to list it as endangered under the CESA. The Commission reviewed the petition for completeness, and pursuant to Section 2073 of the California Fish and Game Code, referred the petition to the Department on 2 August 2018 for evaluation. The Commission gave public notice of receipt of the petition on 17 August 2018. The Department requested a 30-day extension on the 90-day review period on 5 October 2018 which was granted by the Commission at its 17 October 2018 meeting in Fresno, California.

The Department evaluated the scientific information presented in the Petition as well as other relevant information possessed by the Department at the time of review. The Department did not receive any information from the public during the Petition Evaluation period pursuant to Fish and Game Code Section 2073.4. Pursuant to Fish and Game Code Section 2072.3 and Section 670.1, subdivision (d)(1), of Title 14 of the California Code of Regulations, the Department evaluated whether the Petition includes sufficient scientific information regarding each of the following petition components to indicate that the petitioned action may be warranted:

- population trend,
- range,
- distribution,
- abundance,
- life history,
- kind of habitat necessary for survival,
- factors affecting ability to survive and reproduce,
- degree and immediacy of threat,
- impacts of existing management,
- suggestions for future management,
- availability and sources of information, and
- a detailed distribution map.

On 8 November 2018, the Department transmitted its evaluation, entitled *Evaluation of the petition From the Karuk Tribe and the Salmon River Restoration Council to List Upper Klamath Trinity River Spring Chinook Salmon (Oncorhynchus tshawytscha) as Threatened or Endangered,* to the Commission. The Department found that, based upon the information contained in the petition, there was sufficient evidence to indicate that the petitioned action may be warranted, and recommended that the Commission accept the petition (CDFW 2018b). The Commission received the Department’s evaluation at its 12 – 13 December 2018 meeting in Oceanside, California. At its scheduled public meeting on 6 February 2019 in Sacramento, California, the

Commission considered the Petition, the Department's evaluation and recommendation, and the comments received. The Commission found that sufficient information existed to indicate the petitioned action may be warranted and accepted the Petition for consideration. Upon publication of the Commission's notice of its findings, UKTR spring Chinook Salmon was designated a candidate species on 22 February 2019 (California Regulatory Register Notice 2019, 8-Z, 22 February 2019) The Commission referred the petition to the Department on 6 February 2019 with direction to prepare a status review. The Department requested a six-month extension for completion of the status review, which was granted on 12 June 2019 at the Commission's regularly scheduled meeting in Redding, California.

1.4 Department Review

This report contains the results of the Department's review and its recommendations to the Commission regarding this petition. The purpose of this status review is to fulfill the mandate as required by Fish and Game Code Section 2074.6 and to provide the Commission with the most current, scientifically-based information available on the status of UKTR spring Chinook Salmon in California, and to serve as the basis for the Department's recommendation to the Commission. This status review is based on the best scientific information available. It also contains the Department's recommendation on whether the petitioned action is warranted. Further, this status review identifies habitat that may be essential to the continued existence of the species and suggests prudent management and restoration actions.

A draft version of this document was subjected to independent external peer review by a group of anonymous qualified experts. Comments from external peer reviewers are contained in Appendix D.

1.5 Previous UKTR Spring Chinook Salmon Listing Actions and Reviews

1.5.1 State of California Listing Actions

There have been no previous listing actions for UKTR spring Chinook Salmon under CESA. However, UKTR spring Chinook Salmon are on the list of California Species of Special Concern (Moyle et al. 2015).

1.5.2 Federal Listing Actions

In 2011, the Center for Biological Diversity submitted an Endangered Species Act (ESA) listing petition to National Marine Fisheries Service (NMFS) to list UKTR spring Chinook Salmon (called UKTSC in that petition) as endangered based on declines in abundance and distribution. After review, NMFS found that the listing of UKTR spring Chinook Salmon was not warranted. The petition was denied based on the finding that UKTR spring Chinook Salmon were not genetically distinct from UKTR fall Chinook Salmon; the two ecotypes were genetically similar, together forming a single Evolutionarily Significant Unit (ESU). Further, the combined Chinook Salmon populations in the Upper Klamath-Trinity basins were found to be relatively robust, despite declines in the spring ecotype. NMFS regards the UKTR spring Chinook Salmon as a life-history variant evolved from polyphyletic origins that is capable of recovery over time from existing genetic stocks.

In 2017, the Karuk Tribe and Salmon River Restoration Council petitioned NMFS to reconsider its decision and list the UKTR spring Chinook Salmon as endangered. The results of the most recent NMFS review are not yet published at the time of this CESA status review.

1.5.3 Other Independent Status Evaluations

The Department reviewed other independent UKTR spring Chinook Salmon status evaluations from Moyle et al. (2008, 2011, 2015) and Katz et al. (2012). In these independent reviews, the authors chose to analyze the status of UKTR spring Chinook Salmon as if they constituted a distinct ESU. These reviews are largely qualitative and dependent on expert opinion, and therefore their findings should be treated with caution. A 2008 status review commissioned by CalTrout (Moyle et al. 2008) evaluated existing species data and “population trends” for UKTR spring Chinook Salmon and concluded that, although there were no obvious short-term (last 20 years) trends, extirpation is a distinct possibility due to small population sizes. UKTR spring Chinook Salmon life history, which includes adults spending an extended period in fresh water where anthropogenic threats are greatest, makes UKTR spring Chinook Salmon more susceptible than UKTR fall Chinook Salmon to these factors. Moyle et al. (2008) attributes the current status of UKTR spring Chinook Salmon to dams, logging, mining, rural development, harvest, hatcheries, and disease. Without action, the authors warn that warming temperatures caused by climate change would likely lead to extinction. One conservation recommendation offered in this assessment was to declare UKTR spring Chinook Salmon a Distinct Population Segment (DPS) and list it as a threatened species under both ESA and CESA. Other recommendations included dam removal and improved habitat and hatchery management.

In Moyle et al.’s (2011) assessment of native fishes in California, the authors evaluated 129 freshwater and anadromous fish “species” (as defined by the authors) and scored their status based on seven criteria: area occupied, estimated adult abundance, dependence on human intervention for persistence, physiological tolerance, genetic diversity, vulnerability to climate change, and anthropogenic threats. Because the evaluation methods needed to be comparable across diverse taxa with different life histories and levels of information, the scale scoring system used is not as detailed as the analysis the Department uses to inform a CESA status review. In this evaluation, UKTR spring Chinook Salmon scored the lowest of any Chinook Salmon in California, which the authors state is roughly equivalent to the IUCN “endangered” threat level (Moyle et al. 2011). This analysis was used to update the Department’s Fish Species of Special Concern in California (Moyle et al. 2015), which described the analysis used in Moyle et al. (2011) and also rated anthropogenic factors limiting or potentially limiting the viability of UKTR spring Chinook Salmon. Factors rated “High” (i.e., strong contribution to declines and poor status) included blockage by major dams and hatcheries. Factors rated “Medium” included agriculture and grazing, mining, transportation, recreation, and harvest. Management actions recommended as a result of this evaluation included removing mainstem Klamath River dams, restoring cold-water refugia on the Shasta River, managing the Salmon River as a refuge for UKTR spring Chinook Salmon and summer steelhead, investigating hatchery impacts, improved habitat restoration to mitigate impacts from roads and logging, and harvest recommendations (Moyle et al. 2015).

Katz et al. (2012) also analyzed some of the species considered in Moyle et al. (2011). The authors used a similar scaling protocol to categorize risk for 32 taxa of California native fishes. Each group received a composite score ranging from 1 (highest risk of extinction or extirpation) to 5 (reasonably stable at this time). Of the 32 taxa considered, 78% were judged likely to become extinct or extirpated within 100 years. UKTR spring Chinook Salmon were evaluated as a separate species, receiving a high-risk score of 1.6.

2. Biology

2.1 Species Characteristics

Chinook Salmon are semelparous, anadromous, salmonid fishes native to fresh and ocean waters of the North Pacific Rim. Although among the least abundant of all the Pacific salmonids, Chinook Salmon show the greatest life-history diversity and geographic range (Riddell et al. 2018). They are the largest of the Pacific salmon genus *Oncorhynchus*, with adults in northern waters growing as large as 45 kg (99 lbs). The name Chinook refers to the collective Chinookan Native American Tribes of the Pacific Northwest. The species is also known by the common names King Salmon, Tyee, and Quinnat Salmon.

In this status review, the Department uses the common name Upper Klamath and Trinity Rivers spring Chinook Salmon (abbreviated UKTR spring Chinook Salmon) for the early-migrating Chinook Salmon ecotype in the Klamath basin that is the focus of the petition. Other common names for UKTR spring Chinook Salmon include Klamath Trinity spring Chinook, Klamath Trinity spring-run Chinook, and Upper Klamath-Trinity River spring-run Chinook. The name "UKTR Chinook Salmon" is used to indicate the larger UKTR Chinook Salmon ESU containing both UKTR spring Chinook Salmon and UKTR fall Chinook Salmon ecotypes.

Spawning Chinook Salmon are distinguished by their large size, presence of small dark spots visible on both lobes of the caudal fin (also on head and back), and dark pigment at the base of the teeth. Chinook Salmon have a streamlined, fusiform, laterally compressed body shape. The species is characterized by having a large number (>100) of pyloric caeca (McPhail and Lindsey 1970; Hart 1973).

Sea-run Chinook Salmon are dark green to blue-black on their heads and back and silvery to white on the sides and belly. Body color changes to an olive-brown, red, or purplish color during spawning. Males are frequently darker than females and spawning males have a kyped jaw. The anal fin has a white leading edge not set off with a dark pigment line as in Coho Salmon.

Fry and parr are primarily distinguished by large oval spots (parr marks) extending well below the lateral line. However, juvenile characteristics are highly variable and reliable identification is often based on counts of pyloric caeca and meristic traits (e.g., numbers of scales, fin rays, gill rakers).

There are two distinct groups of Chinook Salmon whose adult migration occurs in the spring in California: Central Valley spring-run Chinook Salmon (comprising its own ESU), and Upper Klamath-Trinity Rivers (UKTR) spring Chinook Salmon (a part of the UKTR Chinook Salmon ESU along with UKTR fall Chinook Salmon). The two California ESUs containing spring-returning fish are widely separated spatially—one found in the Central Valley and the other on the North

Coast. The two ESUs are also genetically distant from one another (see discussion in *Section 2.6 Genetics and Genomics and Figure 2.10*).

Additional information on species characteristics can be found in Moyle (1976); Scott and Crossman (1973); Wydoski and Whitney (1979); Morrow (1980); Eschmeyer et al. (1983); Page and Burr (1991).

2.2 Life History and Unique Characteristics

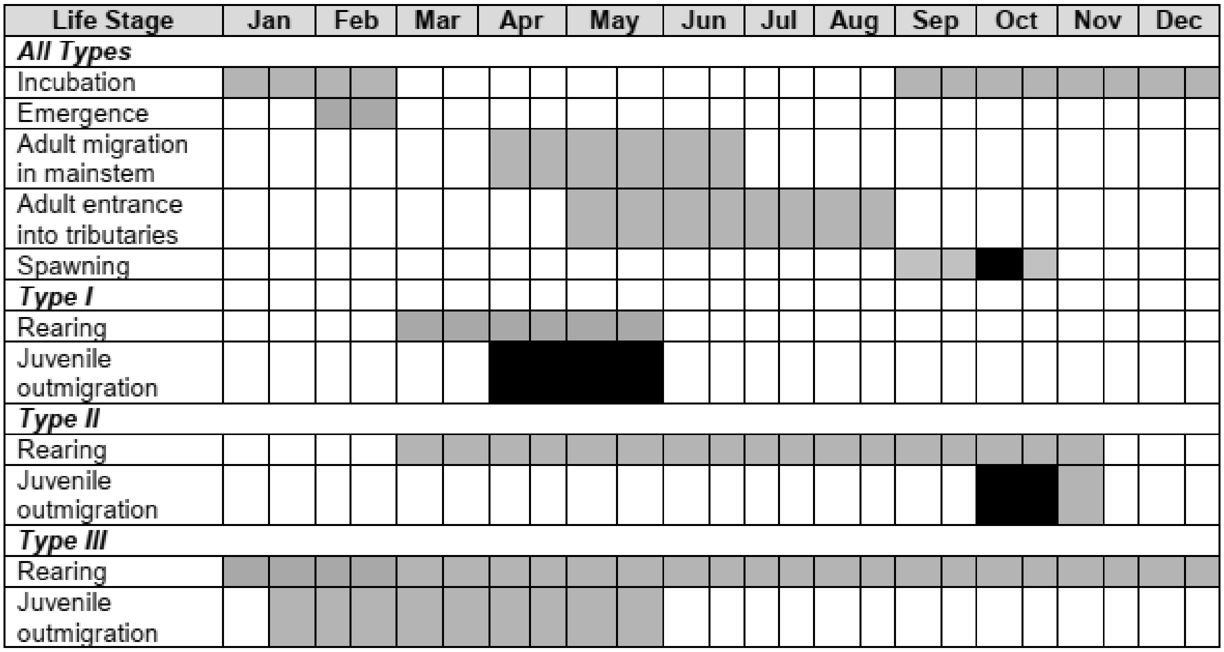
Spawning adult UKTR spring Chinook Salmon enter the Klamath estuary in the spring and summer, from March through July. Proportions of grilse in the three extant UKTR spring geographic locations appear to be moderate to low (Table 2.1). The peak of the spawning migration is May through early June (Moffett and Smith 1950, Myers et al. 1998). Hearsey and Kinziger (2015) found that most of the fish that entered the system in May and June assigned to the Trinity River spring Chinook salmon reporting group. A substantial portion of Chinook salmon returning in July, and only a small fraction thereafter assigned to spring. Fish that assigned to the Klamath River fall Chinook salmon reporting group increased in August, after which they constituted a large proportion of the run until October. Lower Basin fall Chinook salmon started entry in September, peaking in October. And the Trinity fall Chinook salmon reporting group was found throughout the return season in proportions from 22-51 percent of the monthly catch. In the past, a Klamath River summer Chinook Salmon run (July and August) was described by Snyder (1931). UKTR spring Chinook Salmon in the Salmon River spawn from mid-September to late-October in the Salmon River and from September through early November in the South Fork Trinity River (Stillwater Sciences 2009).

Table 2.1. Proportions of UKTR spring Chinook Salmon grilse observed in the Salmon River, South Fork (SF) Trinity River, Klamath River tributaries, and Trinity River tributaries.

	Salmon River	SF Trinity River	Klamath River tributaries	Trinity River tributaries
Years	1995-2019	1992-2018	1981-2018	1980-2018
Grilse Proportion (average)	0.14	0.12	0.17	0.21
min	0.02	0.01	0.00	0.00
max	0.28	0.45	1.00	0.65

Figure 2.1 shows a generalized life-history for UKTR spring Chinook Salmon. Adult migrants enter fresh water with incompletely developed gonads, holding for 2 – 4 months in cold water prior to spawning. Moffett and Smith (1950) noted that adult migration through the Trinity River is rapid, occurring day and night, with a peak two hours after sunset. Fish that enter TRH between September 3 and October 15 are categorized as UKTR spring Chinook Salmon. Many

UKTR spring Chinook Salmon hold just below the hatchery prior to this in June – August; however, the UKTR spring Chinook Salmon initiation of freshwater migration may be artificially affected by hatchery operations. Barnhardt (1994) and NRC (2004) reported that most of the fish entering late in the season during their studies were of hatchery origin. The migration of Trinity River UKTR spring Chinook Salmon has been reported to extend into October (Leidy and Leidy 1984); however, it is unclear whether these late-arriving fish spawn with other UKTR spring Chinook Salmon. Since this was only observed in the Trinity River, these late arrivals may represent spring/fall hybrids of Trinity River Hatchery (TRH) origin.



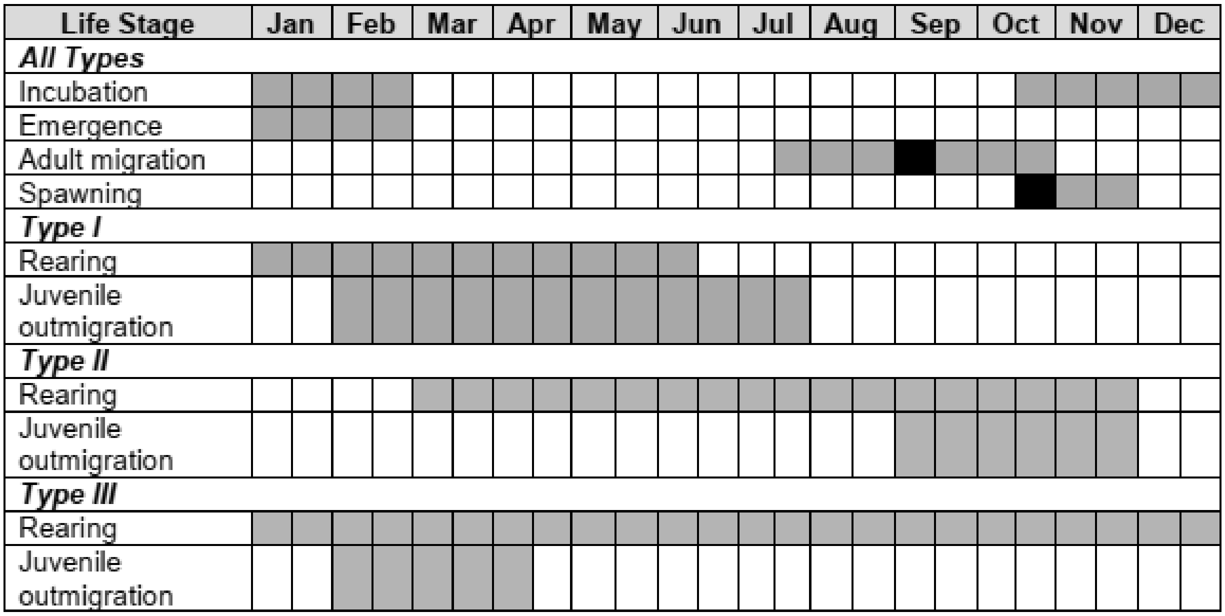
Life Stage	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
All Types																								
Incubation	▨	▨	▨	▨													▨	▨	▨	▨	▨	▨	▨	▨
Emergence			▨	▨																				
Adult migration in mainstem							▨	▨	▨	▨	▨	▨												
Adult entrance into tributaries									▨	▨	▨	▨	▨	▨	▨	▨								
Spawning																	▨	▨	■	▨				
Type I																								
Rearing					▨	▨	▨	▨	▨	▨														
Juvenile outmigration							■	■	■	■														
Type II																								
Rearing					▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			
Juvenile outmigration																			■	■	▨			
Type III																								
Rearing	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Juvenile outmigration		▨	▨	▨	▨	▨	▨	▨	▨	▨														

Figure 2.1. Life-history of UKTR spring Chinook Salmon in the Klamath River. Type I: ocean entry at age 0 in early spring, Type II: ocean entry at age 0 in fall or early winter, and Type III: ocean entry at age 1 in spring. Gray: presence in the river; Black: peak activity. From: SWRCB 2018.

Hatching occurs 40 – 60 days after egg deposition, and alevins remain in natal gravels for 4 – 6 weeks. Both hatching and emergence timing are dependent on water temperature. UKTR spring Chinook Salmon fry emergence occurs in early winter (Leidy and Leidy 1984), extending to late May (Olsen 1996). Prior to construction of Lewiston Dam, fry emergence occurred as early as January. Leidy and Leidy (1984) found that emergence begins as early as November in the Trinity River, and December through February in the Klamath River. Juvenile emigration occurs February through mid-June (Leidy and Leidy 1984).

In contrast to some more northerly (e.g., Columbia River) spring Chinook populations, UKTR spring Chinook Salmon mostly exhibit an “ocean-type,” and only rarely a “stream-type” life-history pattern (Healey 1991, Dean 1995). Stream-type juveniles spend one or more years in their natal rivers prior to migration to the ocean. Ocean-type juveniles are characterized by river outmigration within their first year and an extended estuary residence prior to ocean entry. The ocean-type life history is associated with Chinook Salmon in smaller coastal rivers and lower reaches of larger river systems. Stream-type fish are typically found in headwaters and more northern basins (Healey 1991). Snyder (1931) examined 35 adult UKTR Chinook Salmon scale samples, 83% of which showed an ocean-type growth pattern.

Three rearing types have been identified in UKTR Chinook Salmon (Sullivan 1989): Type I: ocean entry at age 0 in early spring, Type II: ocean entry at age 0 in fall or early winter, and Type III: ocean entry at age 1 in spring. Scheiff et al. (2001) found that 63% of natural Chinook Salmon outmigrants emigrated as Type I, 37% as Type II, and less than 1% as Type III. Wild UKTR spring Chinook Salmon from the Salmon River appear to primarily express a Type II life history (Olson 1996; Sartori 2006). A small number of fish employ the Type III life history, although it does not appear to be as common. For UKTR fall Chinook Salmon in the Klamath River, upstream spawning migration through the estuary and Lower Klamath River peaks in early September and continues through late October (Moyle 2002; FERC 2007; Strange 2012; Figure 2.2). Fall Chinook spawning peaks in late October to early November. Fry emergence extends from early February through early April (Stillwater Sciences 2009), although emergence timing varies by year and tributary depending on temperature.



Life Stage	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
All Types																								
Incubation	▨	▨	▨	▨																▨	▨	▨	▨	▨
Emergence	▨	▨	▨	▨																				
Adult migration														▨	▨	▨	■	▨	▨	▨				
Spawning																				■	▨	▨		
Type I																								
Rearing	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨													
Juvenile outmigration			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨										
Type II																								
Rearing					▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
Juvenile outmigration																	▨	▨	▨	▨	▨	▨		
Type III																								
Rearing	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Juvenile outmigration			▨	▨	▨	▨	▨																	

Figure 2.2. Life-history of UKTR fall Chinook Salmon in the Klamath River. Type 1: ocean entry at age 0 in early spring, Type 2: ocean entry at age 0 in fall or early winter, and Type 3: ocean entry at age 1 in spring. Gray: presence in the river; Black: peak activity. From: SWRCB 2018.

2.3 Taxonomy and Systematics

Chinook Salmon *Oncorhynchus tshawytscha* are one of nine species of the genus *Oncorhynchus*. The genus *Oncorhynchus* is in the family Salmonidae (salmon, trout, and chars) and the Class Osteichthyes (bony fishes). Figure 2.3 shows a complete taxonomic hierarchy for the species. Chinook Salmon are most closely related to and are the sister taxon of Coho Salmon *(Oncorhynchus kisutch)* (Figures 2.4, 2.5). The close relationship of Coho and Chinook salmon, and their separation from other salmon species is consistently shown in phylogenetic studies (e.g., Stearley and Smith 1993; Thomas et al. 1986).

There are numerous non-taxonomic units of Chinook Salmon in California. The most common consist of “runs” of fish returning to a specific drainage (e.g., “the Klamath River”) and/or at a specific time (e.g., “spring”)[1], and Evolutionarily Significant Units (ESUs) (Distinct Population Segments [DPSs] for Pacific Salmon; see below). The currently recognized ESUs of California Chinook Salmon and their listing status under both state and federal law are shown in Table 2.2.

The CESA listing petition addressed in this status review references UKTR spring Chinook Salmon, which are currently recognized as a part of the UKTR Chinook Salmon ESU (e.g., Myers et al. 1998, Williams et al. 2013). In addition to UKTR spring Chinook Salmon, the greater UKTR Chinook Salmon ESU contains a fall migrating ecotype. The spring and fall ecotypes are not reproductively isolated over a substantial portion of their spawning distribution. Snyder (1931) and Moffet and Smith (1950) also refer to a summer run ecotype.

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[1] “Runs” in California are generally defined geographically and/or temporally. Sometimes runs are synonymous with “ecotypes” and sometimes they are not.

Kingdom Animalia
Subkingdom Bilateria
Infrakingdom Deuterostomia
Phylum Chordata
Subphylum Vertebrata
Infraphylum Gnathostomata
Superclass Actinopterygii
Class Teleostei
Superorder Protacanthopterygii
Order Salmoniformes
Family Salmonidae
Subfamily Salmoninae
Genus *Oncorhynchus* (Suckley, 1861) Pacific salmon
Species *Oncorhynchus tshawytscha* (Walbaum in Artedi 1792)

Figure 2.3. Chinook Salmon Taxonomy. Source: *Integrated Taxonomic Information System* (ITIS) Standard Report [2].

Table 2.2. Evolutionarily significant units (ESUs) of Chinook Salmon in California, including ESA/CESA listing status.

Evolutionarily Significant Units	ESA/CESA Listing Status
Southern Oregon and Northern California Coastal Chinook Salmon	Not listed/Not listed
Upper Klamath Trinity Rivers Chinook Salmon	Not listed/Not listed
California Coastal Chinook Salmon	Threatened/Not listed
Central Valley fall-late fall Chinook Salmon	Not Listed/Not listed
Central Valley spring-run Chinook Salmon	Threatened/Threatened
Central Valley winter-run Chinook Salmon	Endangered/Endangered

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[2] Available online (accessed 8 June 2020): https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=161980#null

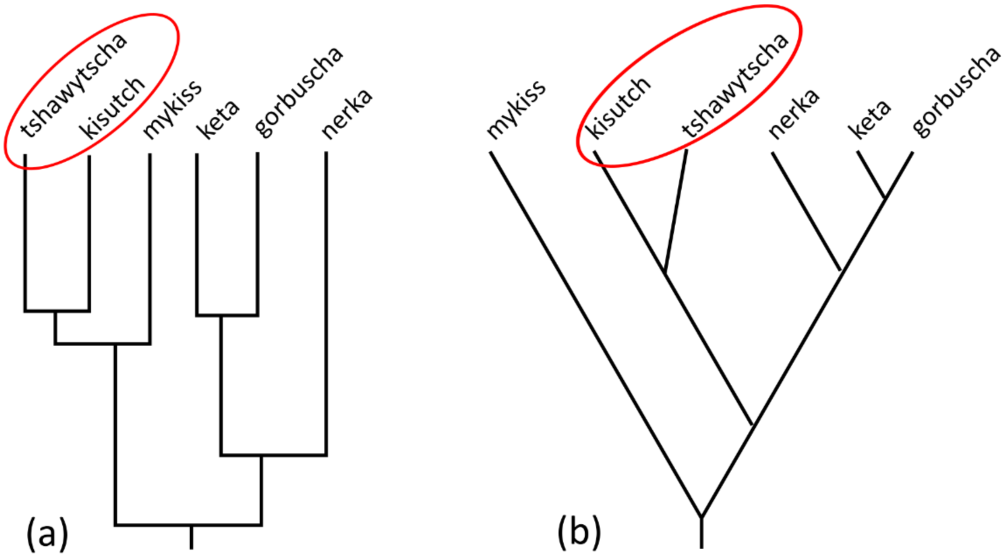

Figure 2.4. Unweighted pair group method with arithmetic mean (UPGMA) Phenogram (a) and Cladogram (b) of mitochondrial DNA data showing genetic relationships of Pacific salmon species. From: Thomas et al 1986, as cited in Stearley and Smith 1993.

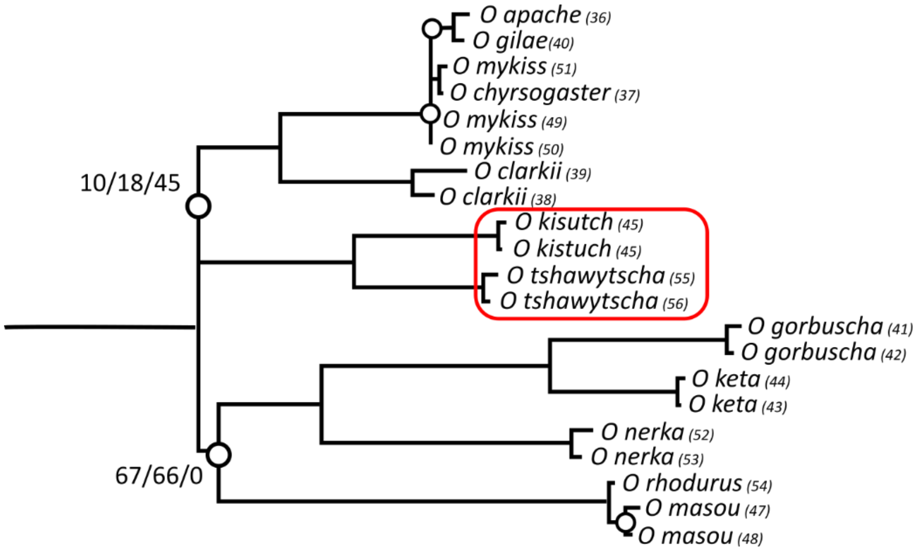

Figure 2.5. Unrooted maximum likelihood phylogram based on the cytochromes data set showing the relationships among members of genus *Oncorhynchus* and close relationship of *O. tshawytscha* and *O. kisutch*. Derived from: Figure 1 in Crête-Lafreniè et al. 2012.

2.4 The Evolutionarily Significant Unit Concept

The federal ESA defines species to include "any subspecies of fish or wildlife or plants, and any distinct population segment (DPS) of any species of vertebrate fish or wildlife which interbreeds when mature." To be classified as a DPS, a population segment must be both discrete (geographically separated, or physiologically, ecologically, behaviorally distinct) and significant to the species (61 FR 4722). Status of a population segment is only considered after determining both discreteness and significance.

The NMFS developed the ESU concept to provide a consistent, meaningful, and appropriately restrictive policy for determining whether a given sub-taxonomic group of Pacific salmon fit the definition of a DPS (Moritz 1994; Waples 1991a). Waples (1991a) defines the ESU as follows: "A population (or group of populations) will be considered distinct (and hence a 'species') for purposes of the ESA if it represents an ESU of the biological species." Two criteria must be met for a taxon/non-taxon to be considered an ESU: 1) it must be *substantially reproductively isolated* from other conspecific population units, and 2) it must represent *an important component of the evolutionary legacy of the species* (Waples 1991a). This ESU definition provides a way to specifically address the discreetness and significance criteria required to classify a Pacific salmon population segment as a DPS.

In past CESA status reviews for California salmon, the Department has recommended, and the Commission has found, federally-recognized ESUs to be an appropriate biological and geographic basis for listing California salmon stocks, e.g., Sacramento River winter-run Chinook Salmon ESU (CESA endangered), Sacramento River spring-run Chinook Salmon ESU (CESA threatened), Southern Oregon-Northern California Coast Coho Salmon ESU (CESA threatened), and Central California Coast Coho Salmon ESU (CESA endangered)(CDFG 1998, 2002).

The Department agrees that the current delineation of the UKTR Chinook Salmon ESU and other surrounding Chinook ESUs depict the most likely boundaries of largely reproductively isolated and ecologically divergent groups of Chinook Salmon populations in the Klamath basin. The ESU approach to delineation of listing units is consistent with previous state and federal salmon listings and the federal approach to species evaluation.

The petition (Karuk Tribe and Salmon River Restoration Council 2018) requests that the Commission classify the UKTR spring Chinook Salmon as a separate ESU and list it as endangered under CESA. The petitioners go on to describe the federal listing request that was the subject of Williams et al. (2011), noting that, at that time, ESA listing was denied because evidence did not warrant reclassification of UKTR spring Chinook Salmon as its own ESU. The petition then claims that recent genetic evidence (a genomic association with early run-timing described in Prince et al. 2017) demonstrates sufficient differentiation between UKTR spring and fall Chinook Salmon to classify UKTR spring Chinook Salmon as a separate ESU. On this basis, a new ESA petition was submitted November 2, 2017. The petitioners assert that evidence supporting a federal listing would also support listing under CESA.

As of the release date of this status review, the NMFS evaluation of the Klamath-Trinity Chinook ESU structure groups UKTR spring Chinook Salmon along with UKTR fall Chinook Salmon as a single ESU: UKTR Chinook Salmon ESU. This ESU was first delineated in Myers et al. (1998) and supported in subsequent federal reviews (Williams et al. 2011, 2013). In both instances, when responding to the relevant listing petition, NMFS did not list the combined UKTR Chinook Salmon ESU due to the relative abundance of the combined spring and fall ecotypes. Further, NMFS did not list the spring ecotype as a separate ESU because of 1) the lack of reproductive isolation of UKTR spring and fall Chinook salmon in the basin, and 2) the finding that UKTR spring and fall Chinook salmon do not represent independent evolutionary lineages. The Department agrees with NMFS that the UKTR Chinook Salmon ESU designation, comprised of both spring and fall elements, is a valid and justifiable construct from both biological and management perspectives.

It is not clear at this time how NMFS will use genomics data of the type described in Prince et al. (2017) in future ESU delineations and the ESA listing process (Pearse 2016; Coates et al. 2018; Fraser and Bernatchez 2001); however, use of a single genomic association to define an ESU may not be appropriate for several technical reasons. (See Waples and Lindley 2018, Waples et al. 2020, and Ford et al. 2020 for detailed discussions of the issues, and *Section 2.6 Genetics and Genomics* of this document for a full discussion.) Recent discovery of a genetic region associated with run-timing does not change our fundamental understanding of the evolutionary history of UKTR spring and fall Chinook salmon.

This CESA status review responds directly to the geographic range and stocks specified in the petition to list. The petition requests that the Commission list UKTR spring Chinook Salmon native to the Klamath and Trinity Rivers as endangered based on information the petitioners argue support its delineation into an ESU separate from the currently recognized UKTR Chinook Salmon ESU. Therefore, this status review and recommendations focus on information for all quasi-populations (also called “population components” in this review) of UKTR spring Chinook Salmon, including hatchery-origin fish in the Klamath and Trinity Rivers.

The Department does not recommend the UKTR spring Chinook Salmon ecotype be considered a subspecies under CESA under the petitioned basis that it qualifies as an independent ESU. However, in order to provide a more complete review, this status review considers (to the extent possible) the status of the combined spring and fall ecotypes that comprise the UKTR Chinook Salmon ESU. In this review the Department considers the UKTR spring Chinook Salmon to be an ecotype of the combined (spring plus fall) UKTR Chinook Salmon ESU and recommends the Commission look to the combined UKTR Chinook Salmon ESU as the proper level at which to ultimately decide status.

2.6 Genetics and Genomics

2.6.1 Role of Genetics and Genomics in Evaluating Chinook Salmon Population Structure

Most genetic studies have used neutral genetic markers (e.g., microsatellite DNA) to quantify the population structure of Chinook Salmon in the Klamath basin and surrounding areas. Neutral markers are not specifically associated with a particular life-history trait and are assumed not to be under direct selection. This class of genetic marker has been, and continues to be, used to investigate and define salmonid listing units and population structure in California and across the Pacific Northwest (e.g. Myers et al. 1998; Banks and Barton 1999; Banks et al. 2000a, 2000b; Kinziger et al. 2013; Williams et al. 2011). Neutral markers are the standard for elucidation of species' evolutionary histories.

More recently, the advent and rapid development of "adaptive" genetic markers has sparked debate within the fisheries genetics community. There is substantial controversy in the scientific community about the use of adaptive genetic markers for defining conservation units. Waples and Lindley (2018), Pearse (2016), Shafer et al. (2015), and Allendorf et al. (2010) provide reviews and cautions. On the one hand, adaptive genetic markers provide putative associations with specific life-history characteristics: the "genetic type" infers information about a phenotype of interest. In the case of UKTR spring Chinook Salmon, the single associated trait of interest is migration timing. Alternatively, neutral markers have been used successfully for decades to delineate populations and ESUs based on more or less reproductively isolated lineages. Neutral markers are used to estimate genetic relationships and evolutionary history of species as a whole, not specific traits. Genes may have an evolutionary history that is different from the species history as illustrated by the distinction between "gene trees" and "species trees."

2.6.2 Genetic Studies

There is a long history of genetic analyses of Chinook Salmon populations in the Upper Klamath and Trinity rivers (e.g., Anderson et al. 2019; Thompson et al. 2019; Prince et al. 2017; Kinziger et al. 2008 a, 2008b, 2013). Most studies used protein (i.e., allozymes) variation or neutral genetic markers (e.g., microsatellite DNA) to investigate population genetic relationships among stocks living in the basin and surrounding areas. Some more recent studies (Prince et al. 2017; Thompson et al. 2019; Anderson et al. 2019; Anderson and Garza 2019) used genomic methods to identify a specific gene region associated with early migration timing in Chinook Salmon.

Myers et al. (1998) originally examined genetic differences between UKTR spring and fall Chinook in the Klamath-Trinity using allozymes and hatchery stocks. They found that spring and fall Chinook Salmon from the same location were more similar to one another than they are to spring and fall Chinook in another location. This is a common pattern of landscape genetic structure called "isolation by distance." This pattern is interpreted as meaning that genetic structure is based more on geography (i.e., proximity) than other factors like run-timing. From this, Myers et al. (1998) concluded that 1) UKTR spring and fall Chinook comprised ecotypes of a single ESU but acknowledged that 2) hatchery propagation of both runs in the basin over many generations likely blurred genetic distinctions between spring and fall fish through unintentional introgression in the hatcheries and in the wild. They were aware of this issue and recommended that their proposed single ESU should be revised pending future genetic analyses. Allozymes are a genetic marker system based on underlying genetic differences in expressed proteins that has been used extensively since the early days of population genetic analyses; however, it is known that the technique lacks power to detect finer genetic differences discernable using DNA-based marker systems. Allozyme markers were largely replaced by microsatellite DNA loci in population genetics evaluations after approximately the year 2000. Microsatellite DNA-based marker systems have been used in many population genetic studies in various taxa to investigate and define population structure.

Banks et al. (2000a), expanding on a previous study of Klamath basin Chinook Salmon (Banks et al. 1999), found greater genetic distance among some UKTR fall Chinook Salmon populations than among UKTR spring and fall Chinook Salmon populations (Figure 2.6). The authors concluded that geographic origin was more important than life history to the overall structure of Chinook Salmon genetic diversity in the basin. This finding contrasted with genetic diversity structuring observed in California Central Valley Chinook Salmon (Banks et al. 2000b). In that study, Central Valley Chinook Salmon populations clustered primarily according to life-history type (i.e., fall/late fall-run, spring-run, and winter-run) resulting "in a tree that had little in common with the geographic origin of samples despite the greater distance between samples from the Central Valley in comparison to distances between samples of the Klamath and Trinity basin" (Banks et al. 2000b, as cited in Williams et al. 2013).

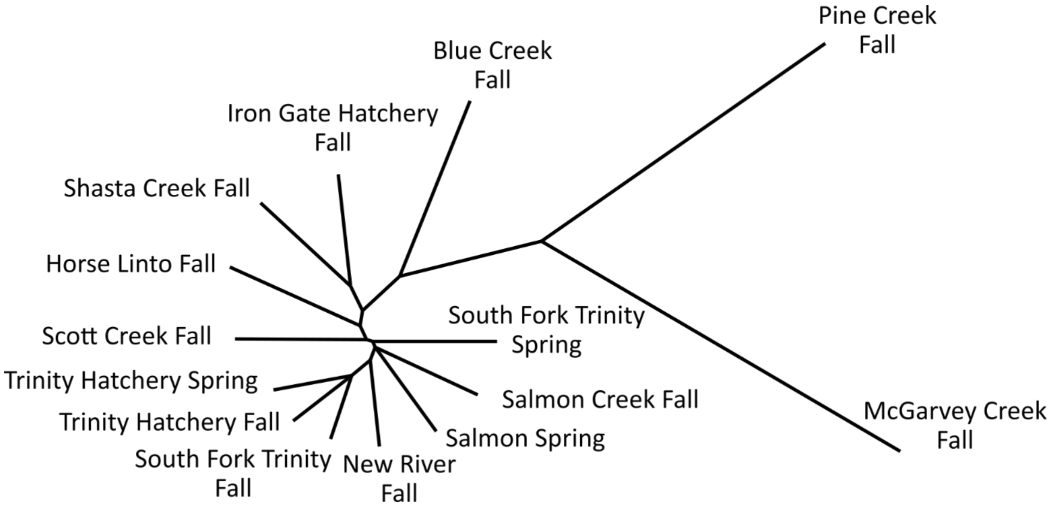

Figure 2.6. Unweighted pair group method with arithmetic mean (UPGMA) phenogram of population samples from UKTR spring and fall Chinook Salmon populations of the Klamath and Trinity basins based on seven microsatellite loci. From: Banks et al. 2000a.

Kinziger et al. (2008a) examined collections from 12 UKTR Chinook Salmon quasi-populations at 17 variable microsatellite loci. The authors examined samples representing all drainages known to have substantial adult Chinook Salmon returns. Collections included both natural-origin and hatchery-origin fish and known spawning areas for both UKTR spring and fall Chinook Salmon. The authors found substantial genetic structure across the basin in four genetically differentiated and geographically separated groups: Upper Basin, Trinity (including spring and fall from the Trinity River Hatchery (TRH) and the South Fork Trinity River), Salmon (containing spring and fall from the Salmon River), and Lower Basin. More importantly, their data indicated that spring- and fall Chinook Salmon life-histories have repeatedly evolved independently (i.e., exhibit a polyphyletic evolutionary history) and in parallel within both the Salmon and Trinity rivers. The authors concluded that UKTR spring and fall Chinook Salmon are not reproductively isolated, unique lineages. This pattern of genetic diversity within the basin was reaffirmed in Kinziger et al. (2013) wherein they analyzed 790 individuals from 10 naturally-spawning and three hatchery populations using 27 microsatellite loci. Similar to their previous study, the authors found a strong pattern of genetic isolation-by-distance, with genetic distance between

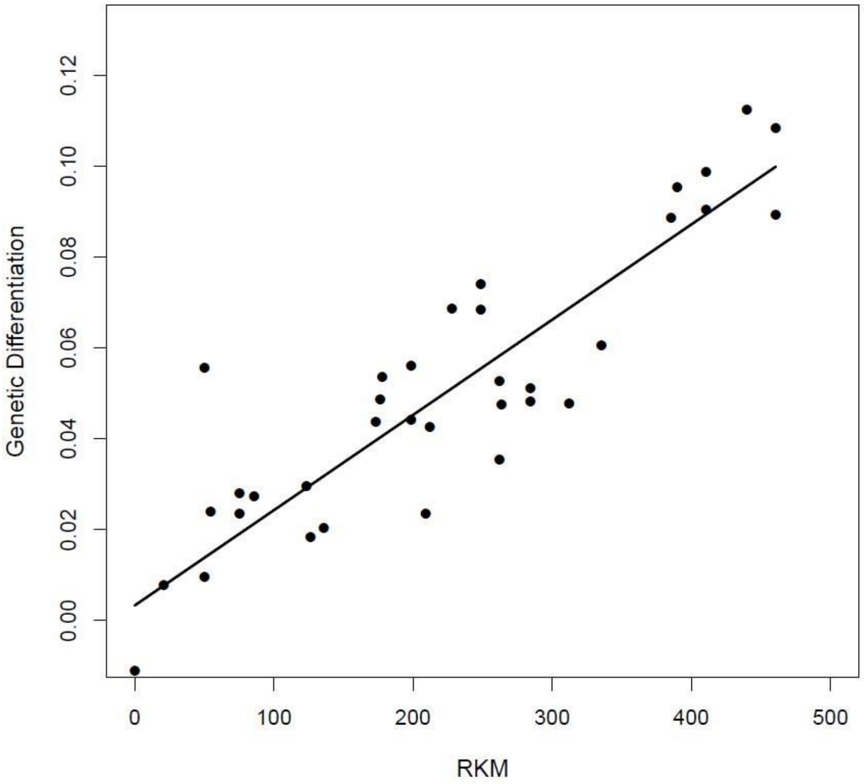

Figure 2.7. Relationship between pairwise genetic differentiation (G'_{ST}) and river distance (RKM) for Klamath River Chinook Salmon above Klamath and Trinity river confluence (excludes Horse Linto Creek) showing pattern of isolation by distance. From: Williams et al. 2013, based on original figure in Kinziger et al. 2013

populations strongly predicted by geographic distance independent of run-timing (Figure 2.7). More significant to this petition, Kinziger et al. (2013) found that UKTR spring and fall Chinook Salmon from the Salmon River exhibited non-significant levels of genetic differentiation and were nearly indistinguishable genetically. They also confirmed the earlier results of Kinziger et al. (2008a, 2008b) that Trinity River Hatchery UKTR spring and fall Chinook Salmon are extremely closely related and that the two run types are more genetically similar to one another than to any other groups in the basin (Figure 2.8). They also examined UKTR spring and fall Chinook Salmon samples from the South Fork Trinity River and found that they were extremely similar to both each other and to TRH Chinook Salmon, but it was noted that the ability to detect differentiation was limited by small samples.

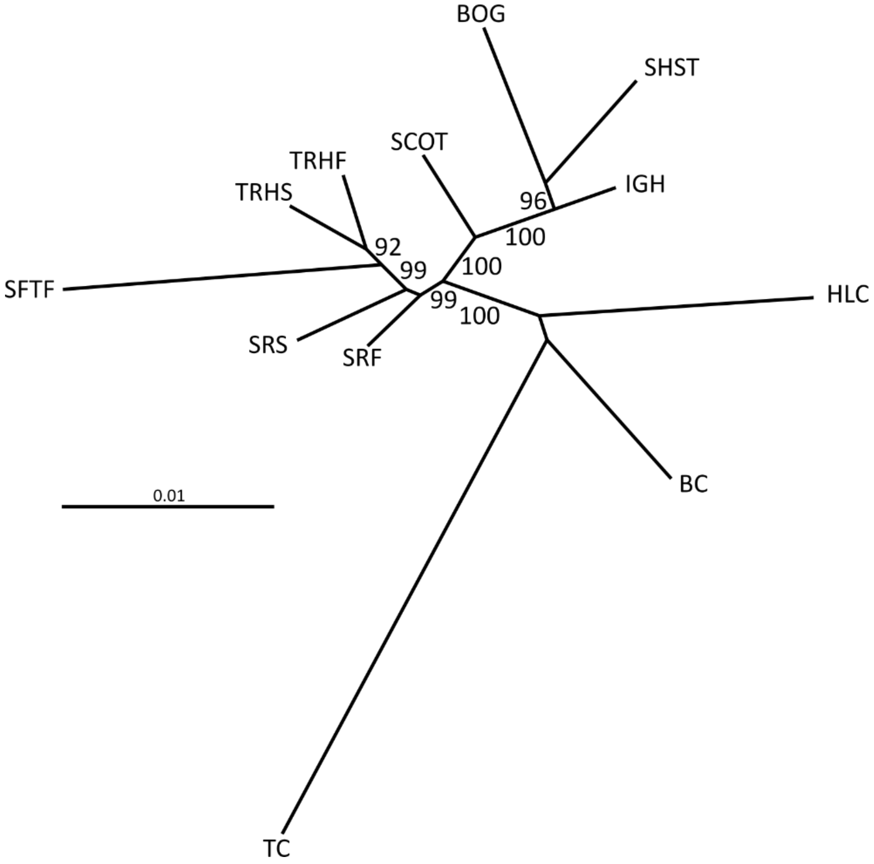

Figure 2.8. Unrooted neighbor-joining tree based on microsatellite DNA data. Branch lengths are equivalent to Cavalli-Sforza genetic distance. Bootstrap support indicated at branch points. Location codes: IGH: Iron Gate Hatchery, BOG: Bogus Creek, SHST: Shasta River, SCOT: Scott River, SRS: Salmon River Spring, SRF: Salmon River Fall, TRHS: Trinity River Hatchery Spring, TRHF: Trinity River Hatchery Fall, SFTF: South Fork Trinity River Fall, HLC: Horse Linto Creek, BC: Blue Creek, TC: Terwer Creek. From: Williams et al. 2013, based on Kinziger et al. 2013.

In summary, the series of studies conducted by Kinziger and colleagues showed that there are greater genetic differences among UKTR Chinook Salmon at different locations within the UKTR system than between the spring and fall migrating life-history types. Additionally, and particularly relevant to this CESA petition, their data suggest that the UKTR spring ecotype arose locally from, and interbreeding with, populations in multiple locations – not from a singular, genetically unique UKTR spring Chinook Salmon ancestor.

2.6.3 Additional Recent Analyses

Recently, Prince et al. (2017) and Thompson et al. (2019) published genetic studies analyzing UKTR spring and fall Chinook. These studies are prominent elements in support of the CESA listing petition (Karuk Tribe and Salmon River Restoration Council 2018). Rapid advances in genomics, the study of the architecture and function of the entire genome of an organism, and methods able to generate very large data sets, have yielded additional genetic results that are relevant to the petitioned assertions addressed in this status review.

Prince et al. (2017) examined population structure in five coastal California and southern Oregon Chinook Salmon ESUs including UKTR spring and fall Chinook from the Trinity and Salmon rivers. They used approximately 55,000 single nucleotide polymorphism (SNP) genetic markers to evaluate population structure. Similar to the results presented in Kinziger et al. (2008a, 2013), Prince et al. (2017) likewise found that overall population genetic structure was much more affected by geographic location than by run timing. Additionally, using the entire genomic data available to them, the authors found that UKTR spring Chinook Salmon did not demonstrate a monophyletic evolutionary history. The authors further concluded that measurements of genetic differentiation in the multiple Chinook Salmon populations they surveyed were consistent with current ESUs.

Prince et al. (2017) also identified and examined a region of the Chinook Salmon genome that has a significant association with run timing, the *GREB1L* region on Chinook chromosome 28, and developed a set of SNP genetic markers in this genomic region. Samples for this study were chosen from the early and late extremes of run-timing distribution to represent different (early and late) run-timing groups. They found that there are two forms (i.e., alleles) of DNA in this region corresponding to the spring and fall migration life-histories. They further stated that the two forms of this region are monophyletic yet are also highly conserved and shared across a broad array of Chinook Salmon populations. Because of this conclusion, the authors assert that, should groups containing the “spring allele” be extirpated, the early migration phenotype could be irretrievably lost.

Prince et al. (2017) also reanalyzed steelhead data from Hess et al. (2016). Similar to the findings from Hess et al. (2016), Prince et al. (2017) also found a significant association between run-timing and *GREB1L*. Heterozygotes were found to migrate at intermediate times between the spring and fall. Based on this, the authors concluded that gene expression at *GREB1L* could not be recessive[3], and that heterozygotes might have lower fitness than either spring or fall homozygotes.[4] If this is true, and heterozygotes experience strong selection, the authors conclude that the spring allele could easily be lost.

Thompson et al. (2019) further examined the genetic distribution of the spring and fall migration associated alleles of the *GREB1L* region in both the Rogue and Klamath rivers. The authors re-sequenced the *GREB1L* region in 64 spring and fall samples using some of the same samples used in Prince et al. (2017). The authors identified new SNPs more closely associated with ecotype than Prince et al. (2017). Using newly developed assays for two of these new SNPs, they genotyped 269 Chinook Salmon collected in early, middle, and late phases of their migration period. The authors found a strong association of return timing phenotype with genotype, with early-returning Chinook Salmon mostly being homozygous for the "spring allele," middle returns mostly heterozygous with both alleles, and late returns mostly homozygous for the "fall allele." The authors concluded that heterozygotes, with their intermediate run timing, may not have the same fitness as fish homozygous for either the spring or fall alleles.[4] If that is the case, if UKTR spring Chinook Salmon (i.e., heterozygotes for the early spring allele) were lost, spring alleles could not be expected to be maintained by heterozygotes.

Thompson et al. (2019) also analyzed nine Chinook Salmon samples from Klamath River archaeological sites using the two new SNPs. Age of the samples ranged from approximately 100 years old to several thousands of years old. Samples were from upper Klamath reaches, above the dams slated for removal in 2022. Both spring- and fall-associated alleles were found in these ancient samples indicating that both ecotypes existed in the Upper Klamath River in historical times.

Thompson et al. (2019) also examined UKTR Chinook Salmon samples from the Shasta and Scott rivers to see whether spring *GREB1L* genetic markers were still present despite the absence of spring runs there. The Shasta River has had only a small and inconsistent UKTR spring Chinook Salmon run since the 1930s. Not surprisingly, the authors only found two individuals in 437 samples labeled Shasta River UKTR fall Chinook Salmon that had spring *GREB1L* markers. The authors also analyzed 425 contemporary UKTR fall Chinook Salmon from the Scott River, again finding only two individuals with the spring *GREB1L* markers. The Scott River has not had an appreciable UKTR spring Chinook Salmon return since the 1970s, so these results are also not

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[3] If a simple complete dominance relationship was expressed there would only be two return types, early (spring) or late (fall). Intermediate return timing of heterozygotes suggests a more complex type of phenotypic expression.

[4] However, Koch and Narum (2020) found that fish with homozygous "mature" (late arriving) genotypes had slightly higher fitness than fish with "premature" (early arriving) homozygous genotypes, with heterozygotes showing intermediate fitness.

surprising. All four fish with the spring allele were heterozygotes. Thompson et al. (2019) did, however, find an appreciable number of the spring *GREB1L* alleles in samples from Salmon River Chinook Salmon, correlating with the relatively larger size of its spring returning component. The authors conclude by discussing considerations for UKTR spring Chinook Salmon stock selection for recolonizing the upper Klamath River post-dam removal.

Analyses of adaptive genetic variation have not been limited to Prince et al. (2017) and Thompson et al. (2019). Anderson et al. (2019) and Anderson and Garza (2019) conducted an extensive DNA sequencing study to further refine the actual genomic region associated with migration timing, thus providing more accurate identification than the markers used by Prince et al. (2017) and Thompson et al. (2019). The authors analyzed approximately 200 Chinook Salmon from both runs at TRH and the Salmon River using a new set of genetic markers (SNPs) that are in tighter correlation with migration timing than those used by Prince et al. (2017).

Anderson et al. (2019) found that a substantial number of individuals analyzed possessed both the spring and fall genetic markers (alleles); i.e., there was a substantial number of heterozygotes carrying both spring and fall alleles. They found that only approximately 60% of Trinity River UKTR spring Chinook Salmon contained only the spring markers. The rest were heterozygous for spring and fall markers and about 5-10% of the samples were homozygous for fall markers. A small percentage of the Trinity River fall Chinook Salmon contained both the spring and fall markers, but most contained only the fall marker. The pattern was somewhat different in the Salmon River, where the UKTR spring Chinook Salmon were predominantly homozygous for the spring allele, yet some individuals contained both markers and a small percentage of Salmon River UKTR spring Chinook Salmon were homozygous for fall markers. The UKTR fall Chinook Salmon pattern in the Salmon River was different. Slightly more than half of the Salmon River UKTR fall Chinook Salmon sampled contained only the fall markers while the rest either contained both markers or contained only the spring marker. On the Klamath River, UKTR fall Chinook Salmon from Iron Gate Hatchery (IGH) were exclusively homozygous for the fall allele. Given that the genetic markers used are in tight statistical association with the genomic region affecting migration timing, this pattern shows that the genetic variants linked to one ecotype (e.g., UKTR spring Chinook Salmon) can be carried in individuals showing a different ecotype (e.g., UKTR fall Chinook Salmon) and vice versa.

Both Prince et al. (2017) and Thompson et al. (2019) found that the *GREB1L* genomic region was highly conserved across multiple other Chinook Salmon ESUs from the Upper Klamath and Trinity rivers and Oregon populations. Anderson et al. (2019) also compared his *GREB1L* genomic data to Central Valley Chinook Salmon populations and likewise found that the spring and fall alleles observed in the UKTR Chinook Salmon were also present in Central Valley spring- and fall-run populations.

Narum et al. (2018) presented strong evidence that the ROCK1 gene, adjacent and closely linked to *GREB1L* on chromosome 28 plays a role in migration timing. Koch and Narum (2020) found that the strongest run-timing association was for markers within the ROCK1 gene and the intergenic region between *ROCK1* and *GREB1L*. The region containing these two genes is highly associated with adult migration timing in Chinook salmon.

In response to the most recent federal ESA petition to list UKTR spring Chinook Salmon, Anderson and Garza (2019) conducted additional analyses expanding on the biology of the *GREB1L* association described in Prince et al. (2017) and other previous studies. The following is a summary of their findings:

1. Whole genome sequencing data reveal a region of the genome near *GREB1L* with variation shared by all spring Chinook Salmon ecotypes surveyed in California, including UKTR spring Chinook Salmon and Central Valley spring-run Chinook Salmon, and winter-run Chinook Salmon.
2. Genotyping of the region of strongest genetic association (RoSA) markers on Chinook Salmon from the Yurok tribal fishery shows that RoSA genotype accurately predicts the freshwater entry time of Chinook Salmon in the Klamath River, but does not predict the level of reproductive maturity or fat content after accounting for sampling date.
3. There is a remarkable degree of spatial and temporal overlap of spring (EE[5]) genotypes, with fall (LL) and heterozygous (EL) genotypes of Chinook Salmon on the spawning grounds of the Salmon River.
4. The proportion of different genotypes from carcasses in the Salmon River in any given year is consistent with limited assortative mating[6] between spring and fall ecotypes.
5. Based on limited assortative mating of ecotypes, heterozygotes are predicted to produce a sizable fraction of the spring and fall Chinook Salmon returns each year.
6. It is unlikely that the substantial genetic exchange between UKTR spring and fall Chinook Salmon in the Klamath basin is solely a consequence of increased introgression due to anthropogenic changes in the last 100 years.
7. The spring migration timing allele is still quite abundant within the Klamath basin.

Results of a recent workshop exploring the state of the science, conservation implications, and future research needs regarding the simple genomic association with run timing in Chinook Salmon and steelhead were documented in Ford et al. (2020). A summary of the areas of agreement and uncertainty among the workshop participants is presented in Appendix D.

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[5] In this notation, E=the spring (“early”) allele, L= the fall (“late”) allele. Possible genotypes and phenotypes are EE, homozygous spring; LL, homozygous fall; EL, heterozygous intermediate.

[6] A mating pattern in which individuals with similar phenotypes mate with one another more frequently than expected by chance.

Although all of the findings and discussion in Ford et al. (2020) are important, the following selected conclusions are excerpted here because they are especially relevant to this status review:

1. A single region in the genome has a strong statistical association with adult run timing.
2. The causal variant(s) for adult run timing remain to be identified.
3. Heterozygotes are likely an important mechanism for the spread and maintenance of the early migration alleles over long time scales.
4. The early and late allelic variants that have been well characterized evolved long ago in each species' evolutionary history. The allelic variants for early migration have not arisen independently via new mutations from the genomic background of late migration individuals in each watershed.
5. Using patterns of genetic variation throughout the genome remains important for identifying conservation units, rather than identifying units based solely on small genomic regions associated with specific traits.
6. Spring Chinook salmon and summer steelhead occupy a specialized ecological niche—upstream areas accessible primarily during spring flow events—that has made them particularly vulnerable to extirpation or decline due to habitat degradation.
7. The evaluation of risk to early returning groups (e.g., spring-returning Chinook salmon, summer steelhead) needs to consider what we now know about the genetic basis of adult return time.
8. The finding that the "early run" trait has a simple genetic basis implies that the "early run" phenotype is at greater risk than if the trait resulted from many genes because loss of the "early" allele(s) equates to loss of the phenotype.

Thompson et al. (2020) provided the most recent study of the genetic basis of migration timing in Chinook Salmon, expanding upon work previously reviewed in this section (e.g., Prince et al. 2017, Narum et al. 2018, Thompson et al. 2019, Koch and Narum 2020). Using samples from the Klamath River, Sacramento River, and Oregon Coast, Thompson et al. (2020) found that a single, small genomic region (region of strongest association, RoSA) was almost perfectly associated with spawning migration timing in Chinook Salmon. However, adiposity and sexual maturity, characters long associated with fall and spring Chinook Salmon ecotypes, were not similarly associated with that gene region. These important life-history features were found to be a consequence of early return and the different environments experienced by early and late migrators.

In Sacramento River Chinook Salmon, two divergent haplotypes were found within both early (E) and late (L) lineages. In the Klamath basin only one haplotype was found per lineage, and in the Columbia River the authors found a similar, though not identical, early lineage RoSA haplotype. This suggested that the early lineage haplotypes may be shared by all early migrating Chinook Salmon.

Using samples from the Salmon River, the authors also found that distinct migration timing does not prevent interbreeding between ecotypes. Natural historic interbreeding between run types thought sufficient to homogenize the genome outside of the RoSA was observed. The fall and spring ecotypes were found to be a result of a “simple, ancient polymorphism segregating within a diverse population.” Using samples from the Oregon Coast, Klamath River, and Sacramento River, they found that heterozygotes were widespread wherever spring returning fish and suitable habitat still existed. Importantly, the authors noted evidence that locally adapted alleles for other traits are still present in Klamath River fall Chinook Salmon.

2.6.4 Patterns of Genetic Structure

The pattern of genetic diversity observed in UKTR Chinook Salmon is best understood in context with other California Chinook Salmon populations. The pattern of genetic structure within the UKTR Chinook Salmon ESU is in stark contrast to that underlying differences between Chinook Salmon migration timing in the Central Valley. Both the Central Valley winter-run and spring-run are listed as separate ESUs under both ESA and CESA. Genetic analyses of Central Valley Chinook Salmon populations show clear genetic differentiation between winter-, spring-, and fall/late fall-run Chinook Salmon (Meek et al. 2016; Clemento et al. 2014; Garza et al. 2007; Figure 2.9). Within the Central Valley, this pattern is consistent with each migration timing life-history strategy having arisen only once (i.e., it is monophyletic) and all three runs represent separate, unique evolutionary lineages. Thus, if one of those ecotypes is lost, it will most likely not reemerge from an existing stock. The heavy introgression between spring- and fall- runs in the Feather and Yuba rivers as a result of previous hatchery practices at Feather River Hatchery, along with dam construction and water management in the Feather, Yuba, and Sacramento rivers, complicates this pattern. However, the introgressed stocks in the Feather River are exceptions caused by anthropogenic actions that resulted in interbreeding and repeated backcrossing between spring- and fall-run Chinook Salmon in that river system. As a result of the pattern of genetic structure and reproductive isolation in Central Valley Chinook Salmon populations, the winter-, spring- and fall/late-fall are considered separate ESUs. Sacramento winter-run Chinook Salmon are listed as “endangered” and Central Valley spring-run Chinook Salmon were listed as “threatened” first under the ESA and subsequently under CESA. Central Valley fall/late fall-run Chinook Salmon are not listed under either act.

On a broader geographic scale, Moran et al. (2013) provide a comprehensive discussion of the complexities of evolutionary lineage, biogeographic differences, and the complex colonization history of Chinook Salmon throughout their range. Those authors examined 19,679 samples from 280 collections using 13 microsatellite loci. They found that the level of genetic divergence between life history types is widely variable. While the interior Columbia River populations showed significant divergence between life-history types, most other populations did not. The authors did include both spring and fall Chinook Salmon from the Trinity River but did not comment on the level of genetic divergence between spring and fall Chinook Salmon ecotypes. In summary, the authors emphasized that evolutionary lineage should be described as the life-history strategy coupled with location and further recommended that recognition of group-specific life-history diversity is important for conservation because restoration and recovery efforts typically target life-history types as opposed to lineages.

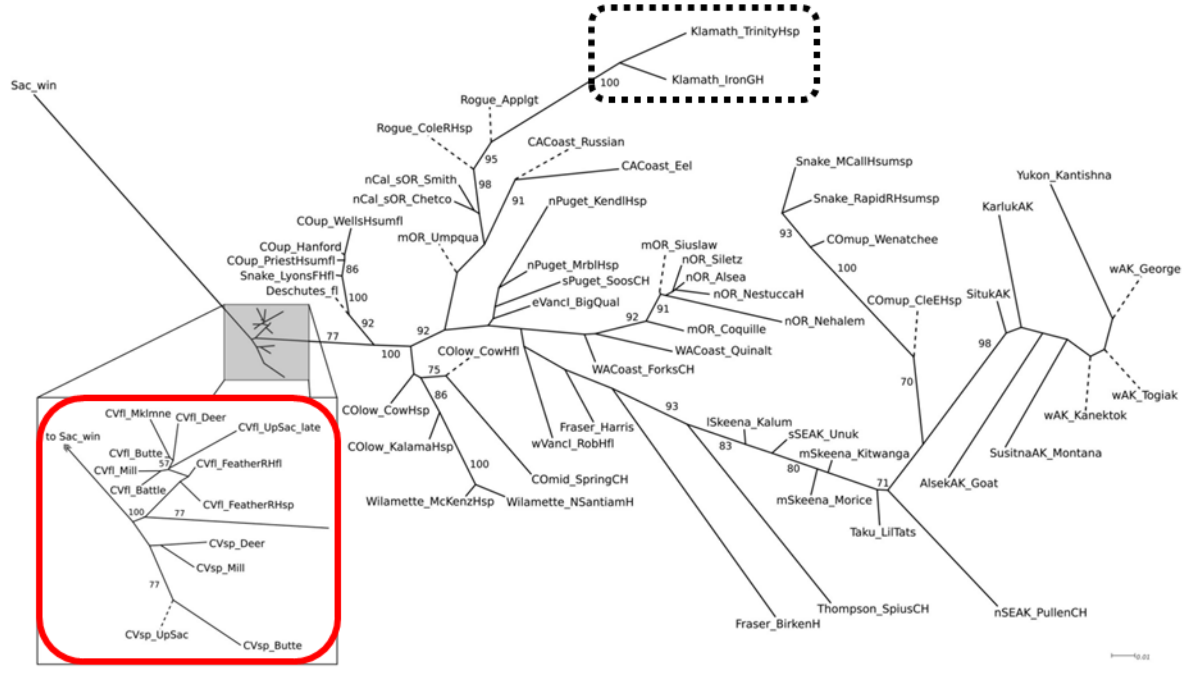

Figure 1

Unrooted neighbor-joining tree constructed with chord distances of 67 populations of Chinook Salmon (*Oncorhynchus tshawytscha*) from California to Alaska in the genetic stock identification baseline (see Table 1 for population details). Dashed lines indicate the position of populations that fall at tree junctions or have very short branch lengths. The Sinona Creek population does not appear in the tree because of the failure of one locus; however, analysis with a truncated set of loci (not shown) revealed clustering with the other Alaska populations. The single collection of Coho Salmon (*Oncorhynchus kisutch*) from California also were omitted.

Figure 2.9. Figure 1 from Clemento et al. (2014) with modification to show genetic relationships of Central Valley Chinook ESUs and Klamath-Trinity Chinook. Central Valley Chinook ESUs in red solid box; Klamath-Trinity samples in black broken dash box.

The mere existence of different life-history strategies does not necessarily mean that they are genetically unique and reproductively isolated. As Moran et al. (2013) discuss, the correlation between life-history strategies and evolutionary lineage is largely situationally dependent. For example, California Central Valley stocks have very distinct irreplaceable Chinook Salmon lineages. Conversely, UKTR Chinook Salmon represent several lineages that are specific to location, not run-timing. Genetically, UKTR spring Chinook Salmon share the same form of early and late alleles that are also found in multiple other spring Chinook Salmon populations within and outside the Klamath basin, and some individuals are heterozygous for both the spring and fall alleles (Anderson and Garza 2019, Thompson et al. 2020). Given that there is clear genetic separation of different migration timing lineages for both neutral (e.g., microsatellite and SNP) and adaptive markers among Central Valley populations but not in the UKTR Chinook Salmon ESU, it would not be appropriate to automatically apply the same ESU designations based on run-timing in the Klamath basin because the pattern of genetic differentiation is markedly different.

Addressing Prince et al. (2017) and Thompson et al. (2019) specifically, the Department recommends an abundance of caution regarding the use of single adaptive genetic markers such as those from the *GREB1L/ROCK1* region when delineating conservation units pursuant to CESA listing decisions. First, the study reported in Prince et al. (2017) was designed to study the genetic basis of migration timing not reproductive isolation. Samples in that study were from opposite ends of the distribution for fall and spring spawning migrants. Modeling from Thompson et al. (2018) suggested overlap in spawning of fall homozygotes, fall-spring heterozygotes, and spring homozygotes. Second, Waples and Lindley (2018) directly address the appropriate use of genomic data, primarily in response to the Prince et al. (2017) paper. They note that at times the patterns of genetic structure will be similar for both neutral (e.g., microsatellite DNA) and adaptive (e.g., *GREB1L/ROCK1*) markers, while at other times, the patterns may be quite different (e.g., as in Prince et al. 2017). This is problematic because if the goal of conservation is to protect biodiversity, then the geographic delineation of conservation units may be drastically different between existing ESUs constructed largely from traditional DNA typing methods and new boundaries reflecting the adaptive genetic markers for a hypothetical petitioner’s life-history trait of choice. Current practice is to protect overall genetic diversity so that a species or ESU will have the greatest possible resilience, allowing it to adapt to future environmental conditions, rather than focus on variation at one specific gene.

Waples and Lindley (2018) go on to explain why a shift to defining conservation units based on adaptive markers alone may be problematic. First, the scientific community does not yet know exactly how this putative marker is distributed in time and space. Prince et al. (2017), Thompson et al. (2019) Anderson and Garza (2019), and Anderson et al. (2019) indicate that the same spring and fall alleles observed in UKTR Chinook Salmon are also present in other Chinook Salmon populations that they surveyed. Second, it is not clear whether the genes identified are actually the ones responsible for migration timing differences. This is still an unresolved but active area of research. Third, details of the pattern of dominance are only recently being explored. Specifically, it is important to know whether spring alleles can persist in fall Chinook Salmon as more recent studies suggest (e.g., Anderson and Garza 2019). Despite having had no appreciable spring-migrating returns in several decades, Thompson et al. (2019) found a handful of fall Chinook Salmon in the Shasta and Scott rivers with the spring *GREB1L* allele. Anderson et al. (2019) found that both UKTR spring and fall Chinook Salmon can indeed contain both the late-returning (fall) and early-returning (spring) forms of *GREB1L* in the same individual. Waples and Lindley (2018) additionally ask why the pattern of genetic diversity associated with this single gene is so different from thousands of other genetic markers?

Waples and Lindley (2018) pose the question of picking a particular trait or gene of interest when defining conservation units. While they agree that migration timing is important and is used in many management contexts, it would be an unprecedented approach to delineation of conservation units. They advocate that both neutral and adaptive genetic information need to be considered in concert with one another. With respect to migration timing specifically, they ask the question "If an early-migrating population is lost, under what circumstances, and over what time period, might it be restored?" Thus, if UKTR spring Chinook Salmon became completely extirpated, could they be restored from existing genetic variation in nearby locations (e.g., Upper Trinity River UKTR spring Chinook Salmon or heterozygous UKTR fall Chinook Salmon). The detection of UKTR fall Chinook Salmon that are heterozygous for the spring and fall alleles of the *GREB1L* gene region suggests this is possible[7]. Importantly, if UKTR spring Chinook Salmon were listed separately from UKTR fall Chinook Salmon, fall-migrating heterozygotes, not protected under CESA, would be expected to produce both protected UKTR spring Chinook Salmon and unprotected UKTR fall Chinook Salmon offspring in the same family. This has potential to present a serious conservation and management dilemma.

2.6.5 Dominance Patterns of the GREB1L/ROCK1 Region

Ford et al. (2020) noted that the dominance patterns at the *GREB1L/ROCK1* region may be complicated and depend on both the evolutionary lineage within a species and how the phenotype is characterized (e.g. freshwater entry vs. spawning time and location). The dominance pattern in Chinook salmon appears to be consistent with either an additive model or dominance of the early allele. There is currently no strong evidence that the early phenotype is recessive.

Thompson et al. (2019) found that early alleles were absent or rare in watersheds where spring Chinook had been largely extirpated. This would not be expected if the early alleles were recessive. Dominance relationships are also hampered by uncertainties associated with accurate run assignment. Expression of the early migrating phenotype is likely also dependent on additional adaptations (e.g., egg and juvenile growth patterns) that have yet to be characterized.

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[7] The differential abundance of UKTR spring Chinook Salmon and their current concentration in the Upper Trinity River suggest that natural recovery of UKTR spring Chinook Salmon in the Klamath River, even after dam removal, could take a long time.

Koch and Narum (2020) in a study of Columbia River Chinook Salmon found that heterozygotes for markers within or upstream of the ROCK1 region had phenotypes that suggested a pattern of dominance for early arrival across populations studied.

Thompson et al. (2020) found a partially dominant or additive dominance relationship in the *GREB1L/ROCK1* region in UKTR Chinook Salmon. Heterozygotes skewed toward early returns but overlapped entirely with both early and late homozygotes. However, the return pattern of heterozygotes in the Sacramento River system is more similar to that for late migrating ecotypes. The authors state that this suggests that dominance relationships are linkage specific and influenced by modifier loci.

2.6.6 Conclusions regarding Genetics and Genomics

There have been substantial genetic analyses conducted on UKTR Chinook Salmon using a variety of methods. Collectively these studies show that geographic location within the Klamath basin largely defines degree of genetic relatedness, as opposed to run-timing. Spring and fall Chinook Salmon in the Klamath basin that are found in the same stream are more similar to one another than to either spring or fall Chinook Salmon in more distant streams. This result strongly validates the “isolation by distance” model for UKTR spring and fall Chinook Salmon in the basin. Population genetic and overlapping spawning distribution data indicate that UKTR spring and fall Chinook Salmon are best described as ecotypes that together comprise local breeding units across the Klamath-Trinity watershed.

The most recent genetic analyses using genomic methods focus on a key region of the Chinook Salmon genome that has a very strong association with run timing. One form of this region is associated with the UKTR spring ecotype and the other with the UKTR fall ecotype. It has also been demonstrated that an individual UKTR Chinook Salmon can have one copy of the spring allele and one copy of the fall allele and that heterozygotes have intermediate, though overlapping, run-timing. Through inheritance from one generation to the next, this means that heterozygotes can produce offspring that display either run-timing phenotype, or potentially produce a single family containing some offspring that return in the spring while other full siblings return in the fall. The spring and fall forms of this gene region are not unique to UKTR Chinook Salmon but appear to be widespread across multiple Chinook Salmon ESUs. Available genetic data, both genome-wide and within the *GREB1L* region suggest historic and current reproductive exchange between UKTR spring and fall Chinook Salmon in the Klamath basin. Given that UKTR spring Chinook Salmon can and do interbreed with UKTR fall Chinook Salmon, and the genotypes that largely determine run timing are universal, it is reasonable to conclude that spring alleles could be introduced from nearby stocks that retain substantial numbers of UKTR spring Chinook Salmon. However, although existing variation in UKTR fall Chinook below Iron Gate Dam retain local adaptations, it is unlikely that existing stocks in the Klamath River would be adequate to naturally restore UKTR spring Chinook Salmon if the run in the Salmon River were lost. The Department agrees with previous federal status reviews (Myers et al. 1998, Williams et al. 2013) that UKTR spring Chinook Salmon do not meet the commonly used genetic criteria to be considered a separate ESU.

The strong genomic association of *GREB1L/ROCK1* and associated regions with adult migration timing (e.g., Prince et al. 2017) is an important result that sheds light on the genetic underpinnings of early run timing in Chinook Salmon and other salmonids. However, the Department finds that this genomic association is only one part of the total evolutionary heritage of UKTR spring Chinook Salmon and, by itself, is not sufficient or appropriate differentiation to create a new UKTR spring Chinook Salmon ESU.

3. Range and Distribution

3.1 Range

Chinook Salmon spawning populations range across the North Pacific Rim from California to Alaska in North America and into Asia from northern Japan to the Palyavaam River in Siberia (Augerot and Foley 2005; Figure 3.1). Spawning populations in North America range from Kotzebue Sound in Alaska to the southernmost populations in California's Central Valley. Except in some drainages of Kamchatka, Chinook Salmon distribution in Asia is sparse and the species is best represented in the Pacific Northwest of North America. The inland range of the species has been truncated in many places by dam construction and habitat alteration.

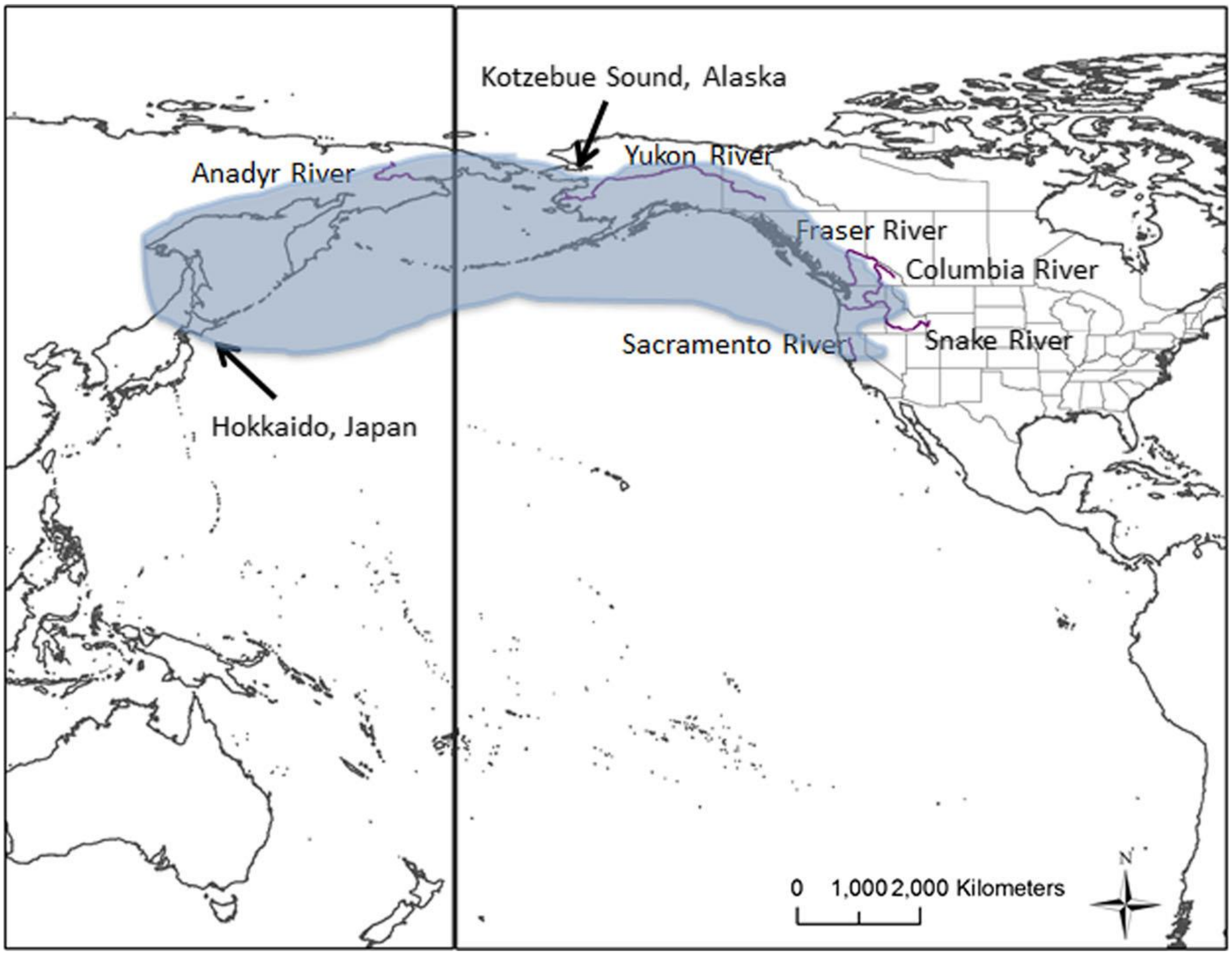

Figure 3.1. Native range of Chinook Salmon. The shaded region represents approximate current freshwater and marine distribution. From: Bourret et al. 2016, citing Healey 1991 and Augerot 2005.

Chinook Salmon have also been translocated to many non-native areas where they are either farmed or exist as a naturalized species. Notable translocations include the Great Lakes, Patagonia, and New Zealand, where naturalized populations have been established. A list of non-indigenous Chinook Salmon occurrences in the U.S. can be found at: https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=920.

The UKTR Chinook Salmon ESU contains both spring and fall ecotypes. The fall ecotype, as in historical times, is widely distributed across the Klamath-Trinity basin (below dams). Both ecotypes have experienced historical range truncations due to dam construction in both the Klamath and Trinity rivers.

The UKTR spring Chinook Salmon ecotype historically ranged throughout the Klamath and Trinity river basins, including upstream of current impassable dams. Holding and spawning occurred in larger tributaries (e.g., Salmon River) and, depending on flows, in some smaller tributaries. UKTR spring Chinook were historically abundant and widely distributed in major Klamath basin tributaries, e.g., Salmon River, Scott River, Shasta River, South Fork Trinity River, and North Fork Trinity River (Moffett and Smith 1950).

The current range of the UKTR Chinook Salmon ESU is restricted by dams to the lower portions of the Klamath and Trinity Rivers. Only the Upper Trinity River, Salmon River, and the South Fork Trinity River currently contain spawning assemblages of the UKTR spring Chinook Salmon ecotype. In the Salmon River, approximately 285 rkm (177 RM) are accessible to UKTR spring Chinook Salmon (West 1991). However, much of that is underutilized or unsuitable for spawning. In the Salmon River, most spawning occurs in the South Fork. UKTR spring Chinook Salmon redds have been found in smaller Salmon River tributaries such as Nordheimer, Knownothing, and Methodist creeks. Small numbers of UKTR spring Chinook Salmon have been observed in Elk, Indian, Clear and Wooley creeks.

Trinity River Hatchery (TRH) also produces hatchery UKTR spring Chinook Salmon. Many of the fish returning to the Trinity River are of hatchery origin. However, although a large proportion of hatchery-origin spawning fish return to TRH, a substantial portion of annual returns to natural spawning areas in all years are of natural-origin (see also *Section 6.7 Factors Affecting the Ability to Survive and Reproduce, Hatcheries*).

3.2 Historical and Current Distribution

The Klamath River basin is California's second largest river system, draining a watershed of approximately 40,404 square km (15,600 square miles). The watershed is commonly divided into the Lower Klamath River below Klamath Lake, the Upper Klamath River above Klamath Lake, and the Trinity River basins. Diverse climate and landscape are observed across the basin. Unique among Pacific drainages, the Klamath basin starts in lower gradient marshes and inland desert environments, transitioning to higher gradient slopes below Klamath Lake (Stanford et al. 2011; Thorsteinson et al. 2011).

Anadromous fish have been blocked from the Oregon reaches of the upper Klamath basin since 1918 when Copco No.1 Dam was constructed (Figure 3.2; USDI et al. 2012). Currently, anadromous fish have access to about 306 km (190 miles) of the Klamath River (from Iron Gate Dam, near the Oregon border in Siskiyou County, to the Pacific Ocean at Requa in Del Norte County). Approximately 1,296 km (805 miles) of suitable Chinook Salmon habitat was estimated to have been lost due to the construction of Iron Gate Dam (CDFG 1965). This estimate was updated by Hardy and Addley (2006) to approximately 1,128 km (701 miles) of spawning habitat above the dam.

Historically, UKTR spring Chinook Salmon may have been as or more abundant than UKTR fall Chinook Salmon in the Klamath basin (Moyle 2002). It is likely that on the order of hundreds of thousands of fish occupied tributaries throughout the basin including the Sprague and Williamson rivers in Oregon (Moyle 2002). Tribal oral histories, historic photographs, early scientific reports, and first-hand accounts of the earliest non-native explorers of the Klamath basin all describe prolific runs of both UKTR spring and fall Chinook Salmon migrating into the headwaters of the Klamath River upstream of Upper Klamath Lake (Hamilton et al. 2005).

The Trinity River is the largest tributary to the Klamath River and drains approximately 3,546 square km (1,369 square miles) of watershed. The headwater streams originate in the Trinity Alps and Trinity Mountains in eastern Trinity County. The river flows 277 km (172 miles) south and west through Trinity County, then north through Humboldt County and the Hoopa Valley and Yurok Indian reservations until it joins the Klamath River at Weitchpec, about 64 rkm (river kilometers; 40 river miles (RM)) from the Pacific Ocean. Anadromous fish passage is blocked by Lewiston Dam approximately 177 rkm (110 RM) upstream from the mouth of the Trinity River.

Historical UKTR spring Chinook Salmon spawning in the Trinity River occurred in the East Fork, Stuart Fork, Coffee Creek, and the mainstem Upper Trinity River (Campbell and Moyle 1991). Approximately 56 km (34.8 miles) of prime spawning and rearing habitat for UKTR Chinook Salmon was blocked by construction of Trinity Dam in 1962 and Lewiston Dam in 1963. Small numbers of UKTR spring Chinook Salmon are currently observed in Hayfork and Canyon creeks, as well as in the North Fork Trinity, South Fork Trinity, and New rivers. Of these, only the South Fork Trinity River is documented to be composed of natural-origin fish. UKTR spring Chinook Salmon spawn in the New River and North Fork Trinity River; however, it is not known whether these are separate populations (W. Sinnen, CDFW, personal communication, 2020). In the South Fork Trinity River, LaFaunce (1967) found that UKTR spring Chinook Salmon spawned from about 3 km (1.9 mi) upstream of Hyampom. The authors also noted spawning in Hayfork Creek for approximately 11 km (6.8 miles). The highest density of redds in the South Fork Trinity River was between rkm 60.7 (37.7 miles) and 111.8 (69.5 miles) in 1964 (LaFaunce 1967) and 1995 (Dean 1996).

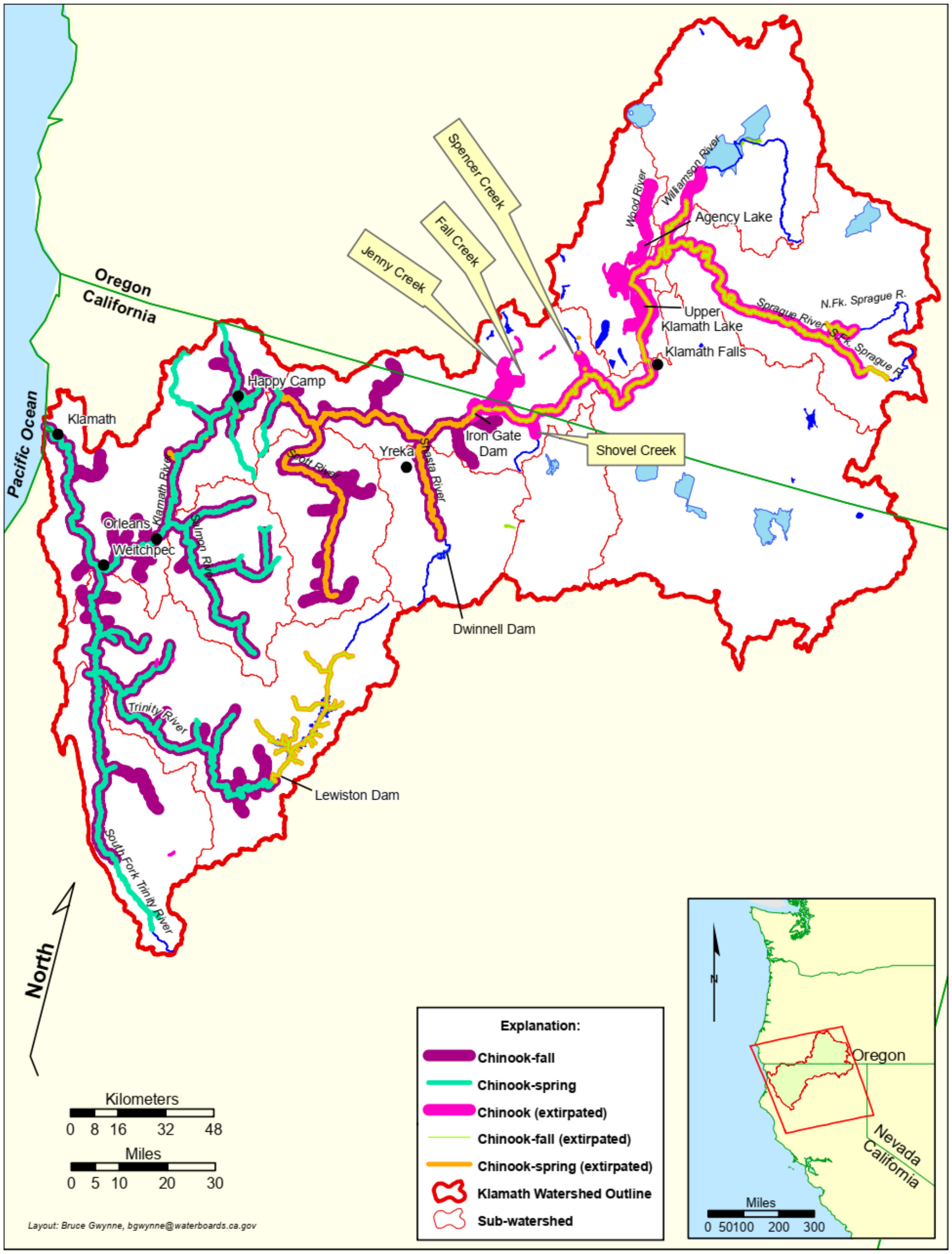

Figure 3.2. Current and historical (extirpated) distribution of UKTR Chinook Salmon in the Klamath and Trinity Rivers (Original map from Carter and Kirk (2008). Streams shown as "extirpated" do not differentiate between UKTR spring and fall Chinook Salmon. Data sources: Hamilton et al. 2005, p. 12; Moffett and Smith 1950, pp. 23 and 27; Moyle 2002, p. 259; USFS 1996; USFS 2006.

UKTR spring Chinook Salmon also historically spawned in the tributaries of the Upper Klamath River basin (Moyle 2002; Hamilton et al. 2005; Hamilton et al. 2016) with large numbers spawning upstream of Klamath Lake in the Williamson, Sprague, and Wood rivers (Snyder 1931). The earliest reference to Chinook Salmon in the Upper Klamath River that the Department is aware of (referenced in Lane and Lane Associates 1981) is Fremont's May 1846 observation of large numbers of salmon at the outlet of Klamath Lake. Based on migration timing, these were likely UKTR spring Chinook Salmon.

Hamilton et al. (2005) conducted a study of the historical distribution of anadromous fish above Iron Gate Dam on the Klamath River. They found substantial evidence that, prior to dam construction, large numbers of both spring and fall Chinook Salmon migrated as far as the Sprague River (OR). The authors found numerous accounts of Chinook Salmon in tributaries of Upper Klamath Lake (e.g., Williamson and Sprague Rivers). Hamilton et al (2016) note that it is possible that fall Chinook (migrating August-October/November) may have only reached Upper Klamath Lake and further tributaries in wetter years.

Spring-migrating (April-August) Chinook, because of their earlier run-timing, and possibly their smaller size, may have more consistently accessed those upper basin streams. This suggests a possible mechanism for that may have resulted in more substantial historical reproductive isolation of UKTR spring and fall Chinook Salmon runs.

Large runs of UKTR spring Chinook Salmon are also thought to have historically returned to the Shasta, Scott, and Salmon rivers (Moyle et al. 1995). Wales (1951) reported that only 8% of the historic salmon returns to the Shasta sub-basin were UKTR fall Chinook Salmon. Dwinell Dam, built in 1926 on the Shasta River, blocked approximately 22% of the spawning habitat in that system (NRC 2004).

Myers et al. (1998) also speculated that the spring ecotype may once have been the dominant Chinook Salmon run in the Klamath River basin. Historically, large numbers of spring Chinook Salmon migrated through the Mid-Klamath River to the Upper Klamath River basin prior to dam construction. Upstream distribution was truncated by dam construction. Blockage by dams also restricted UKTR Chinook Salmon to downstream reaches, exposing then to warm Klamath River main stem water temperatures. This likely limits the quality and quantity of the ESU as a whole but may disproportionately affect critical UKTR spring Chinook Salmon adult holding locations.

Currently, spawning aggregations of UKTR spring Chinook Salmon are mainly found in three places in the Klamath-Trinity: Upper Trinity River, South Fork (SF) Trinity River, and Salmon River. Small numbers of UKTR spring Chinook Salmon are found in a few other places with intermittent occupancy. These include the Trinity River tributaries Hayfork Creek, North Fork Trinity River, and New River. Miscellaneous monitoring of UKTR spring Chinook Salmon in Klamath Tributaries can include tributary creeks in both the USFS Orleans/Ukonom and the US Forest Service (USFS) Happy Camp Ranger Districts. Reported numbers of UKTR spring Chinook Salmon in both drainages are incidental to summer steelhead surveys conducted by USFS (Dan

Troxel, CDFW, 10/29/2019, personal communication). Soto et al. (2008) reported that spring Chinook Salmon can also be found in Mid-Klamath tributaries with cold, deep holding pools such as Dillon, Clear, Elk, Indian and Thompson creeks; however, these occurrences are usually at very small numbers (10 or less).

UKTR fall Chinook Salmon spawn in all reaches of the Salmon River mainstem. Adult UKTR spring Chinook Salmon rarely spawn in the lower Salmon River mainstem; however, some adults have been observed on redds within the upper mainstem above Crapo Creek (RM 15.4) when conditions are good.

- **Wooley Creek (RM 5.0):** UKTR fall and spring Chinook Salmon are known to occupy suitable habitat up to Big Meadows Creek (RM 15.8) within the mainstem of Wooley Creek. However, most annual spawning and rearing occurs below a bedrock chute located at RM 9.6.
- **Nordheimer Creek (RM 14.9):** Adult fall Chinook Salmon are found along 2.6 miles of Nordheimer Creek. However, most spawning and rearing occurs within the mainstem below the fish ladder at RM 1.7. In addition, UKTR spring Chinook Salmon are commonly observed holding within this lower reach.

The South Fork of the Salmon River holds the majority of both UKTR fall and spring Chinook Salmon in the Salmon River. Spring Chinook Salmon are known to occupy habitat that extends above the Little South Fork (RM 28). When stream flows and river conditions are favorable, fall-run Chinook are found as far as Cecilville (RM 22); however, most fall Chinook salmon are spawn below the Matthews Creek boulder sieve around RM 10.3.

- **Knownothing Creek (RM 2.4):** UKTR fall Chinook salmon spawn within 2.5 miles of the Knownothing Creek mainstem, as well as the lower East Fork for approximately 0.6 RM and the West Fork for approximately 0.3 RM. There are no records of UKTR spring Chinook Salmon spawning within this watershed.
- **Methodist Creek (RM 6.4):** UKTR fall Chinook Salmon spawning occurs along the mainstem about 0.9 miles but may extend farther during high flows to river mile 2.4. There are no records of UKTR spring Chinook Salmon holding or spawning in this tributary.
- **Plummer Creek (RM 13.5):** Both UKTR fall and spring Chinook Salmon are known to occupy suitable habitat within the lower mile of the Plummer Creek mainstem.
- **East Fork Salmon River (RM 20.5):** UKTR spring Chinook Salmon are found along the mainstem up to Shadow Creek (RM 4.8). There are no records of fall Chinook Salmon spawning in the East Fork Salmon River.

UKTR spring Chinook Salmon occupy suitable habitat in the North Fork Salmon River as far as Big Creek (RM 26.5). Under high flow conditions, fall Chinook Salmon have been observed spawning as far upstream as Sawyers Bar (RM 14.8). However, both fall and spring Chinook Salmon primarily spawn within the mainstem of the North Fork up to the Little North Fork (RM 11).

- **Little North Fork (RM 11):** UKTR fall and spring Chinook Salmon are known to spawn within the mainstem to Specimen Creek (RM 2.3).

In the Salmon River, spawning starts in mid-September, whereas in the South Fork Trinity River spawning begins in late-September with a peak in mid-October (LaFaunch 1967). UKTR spring Chinook Salmon spawning in the Trinity River begins 4-6 weeks earlier than for UKTR fall Chinook Salmon (Moffett and Smith 1950). Historical overlap in UKTR spring and fall Chinook Salmon spawning areas may have been less than is currently observed. Current spatial separation of UKTR spring and fall Chinook Salmon spawning in the Klamath-Trinity basin is at approximately 518 m elevation. In the South Fork Trinity River, most UKTR spring Chinook Salmon spawning occurs upstream of Hitchcock Creek, above Hyampom Valley. Most UKTR fall Chinook Salmon spawning is below Hitchcock Creek (LaFaunce 1967; Dean 1996). Spawning area overlap was reported to occur in October in the East and North Forks Trinity River, creating conditions suitable for interbreeding of UKTR spring and fall Chinook Salmon (Moffett and Smith 1950). UKTR spring and fall Chinook Salmon spawn timing in the Salmon River overlaps (as illustrated above), but redds above Matthews Creek are mostly from the spring ecotype.

All UKTR spring Chinook Salmon runs in the Upper Klamath Basin are thought to have been in substantial decline by the early 1900s and were extirpated in the Upper Klamath River by the completion of Copco No. 1 Dam in 1917 (Snyder 1931). Neither spring nor fall Chinook Salmon currently exist above the dams. However, dam removal is anticipated to begin 2022 if permits are received on schedule and is likely to result in migration of UKTR fall Chinook Salmon to the Upper Klamath River. Removal of barriers to migration will also provide conditions that allow natural expansion of UKTR spring Chinook Salmon to historical reaches of the Klamath River; however, small numbers and limited current distribution in the Klamath River may extend the time necessary for natural UKTR spring Chinook Salmon expansion.

In contrast to UKTR spring Chinook Salmon, UKTR fall Chinook Salmon are broadly distributed in the Klamath-Trinity Watershed. They are currently found throughout the Klamath-Trinity basin below dams that form the limit of anadromy. UKTR spring Chinook Salmon spawning areas overlap substantially with those for UKTR fall Chinook Salmon (Figure 3.2).

3.3 Ocean Distribution

The Department evaluated ocean distribution of TRH hatchery-origin UKTR spring Chinook Salmon using coded wire tag (CWT) data available through the Regional Mark Processing Center (www.rmis.org). Individual CWT codes were identified as UKTR spring Chinook Salmon using the species code (Chinook), run type code (1) and hatchery location code (TRH). Recoveries expanded for hatchery production (the proportion of total released fish that were CWT tagged and adipose fin-clipped) and sample rate (the proportion of the fishery by time and area that was observed) were summarized by ocean salmon fishery management area as described in the Pacific Fishery Management Council's (PFMC) Salmon Fishery Management Plan (FMP; PFMC 2016).

Coded-wire tag data recovered from commercial and recreational ocean salmon fisheries since brood year 1976 show that the ocean distribution of Trinity River Hatchery-origin UKTR spring Chinook Salmon ranged from British Columbia, Canada, to San Luis Obispo Bay, California (N = 6,281). Recoveries north of Cape Falcon, Oregon, were uncommon (N = 83 recoveries, 1.3% of all recoveries) and occurred outside the boundaries of available fisheries management. Recoveries south of Point Sur, California, were also uncommon (N = 7), though within reach of potential management actions.

4. Status and trend

4.1 Structure and Function of Viable Salmonid Populations

Salmon have strong fidelity to breeding in the stream of their origin. This provides the potential for substantial reproductive isolation of local breeding populations and adaptation to local environmental conditions. Isolated populations are subject to different levels of genetic drift and natural selection regimes that tend over time to result in differences between them. In addition, populations arising through colonization or artificial propagation, and populations that have experienced recent drastic reductions in abundance, are often genetically different from the population from which they were derived. Salmon also naturally exhibit variable amounts of exchange among populations that connect them genetically and make them more alike. Even small amounts of gene flow between stocks (e.g., due to straying or interbreeding of ecotypes) can prevent complete separation of populations unless there is strong differential selection to maintain that separation (Nei 1987). The amount of exchange observed among populations is influenced by natural and/or anthropogenic environmental factors like stream blockages (e.g., sandbars at the mouths of rivers or road crossings) and straying. Because of these factors, salmon populations tend to be largely, but often not completely, isolated.

Levins (1969) proposed the concept of the metapopulation to describe a “population of populations.” Metapopulations are comprised of subpopulations of local breeding groups, with limited exchange among the subpopulations so that they exhibit both some level of isolation and connectivity. Similarly, larger assemblages (e.g., all breeding populations in a watershed) can themselves form a metapopulation due to the connection between them afforded by natural straying. Fragmentation of this structure can affect the ability of populations to respond to natural environmental variation and catastrophic events. Differential productivity among habitat patches can lead to a “source-sink” relationship in which some highly productive habitats support self-sustaining subpopulations, whereas other less productive habitats persist only through migrants from nearby places.

Using the best scientific information available, this review considers the UKTR spring Chinook Salmon to be an ecotype of the combined UKTR (spring plus fall) Chinook Salmon ESU. Spring and fall Chinook Salmon ecotypes arrive at the spawning grounds at different times but have overlapping spawning times and locations (see *Section 3 Range and Distribution*). Because of this, the two ecotypes are not substantially reproductively isolated (Myers et al. 1998; Williams et al. 2013; Kinziger et al. 2008a, 2008b, 2013), and UKTR Chinook Salmon populations (i.e., together comprising the UKTR Chinook Salmon ESU) may contain both spring and fall ecotypes. In parts of this document the Department identifies geographically and temporally distinct groups of UKTR spring and/or fall Chinook Salmon as “population components” or “quasi-populations.” However, the Department acknowledges that, based on evidence of substantial gene flow between them, the UKTR spring and fall Chinook Salmon are ecotypic diversity components of any given combined (spring and fall) UKTR Chinook Salmon population.

4.2 Sources of Information

The Department reviewed all available data sources for this status review. Sources included literature review, the CESA listing petition, previous federal status reviews, Department and other agency reports and documents, historical and tribal reports.

The Department is fortunate to have relatively a long time-series of escapement estimates (1978 – present) for both UKTR spring and fall Chinook Salmon in the basin; however, data collection methods and other sampling features differ over time and by location. In addition, different monitoring entities may use different data collection and sampling methods. Therefore, although time-series data in the places where the majority of UKTR spring Chinook Salmon are thought to return to spawn are fairly consistent, the Department acknowledges shortcomings in sampling and data collection that may affect absolute abundance estimates and analyses based on them. However, the Department finds that the existing abundance data are the best available scientific data for status and trend evaluation over the monitoring period.

4.3 Abundance and Trend

Abundance and trend metrics were calculated using available data for UKTR spring Chinook Salmon, UKTR fall Chinook Salmon, and combined UKTR spring and fall Chinook Salmon genetic diversity groups within the basin using spawning adult estimates ranging back as far as 1978. The UKTR spring Chinook Salmon status and trend was estimated for population components in the Upper Trinity River (above Junction City Weir), South Fork Trinity River, and Salmon River. The UKTR fall Chinook Salmon status and trend are analyzed for population components in Mainstem Klamath River (excluding IGH returns), Bogus Creek, Scott River, Shasta River, Salmon River, and Mainstem Trinity River (excluding TRH returns; see Hatcheries section). Groupings based on genetic affinity include combined UKTR spring and fall Chinook Salmon elements comprising Klamath and Trinity river groups.

Some additional tributaries of the Trinity River are monitored for UKTR spring Chinook Salmon. These streams contain small numbers of fish in comparison to the three main UKTR spring Chinook Salmon aggregations. Miscellaneous monitored Trinity River tributaries include Hayfork Creek, South Fork Trinity River, Canyon Creek, North Fork Trinity River, and New River. Snorkel surveys for adult salmonids on these streams begin in mid-July and are completed by the end of August. Based on time of freshwater entry, location, and survey timing these surveys are thought to target UKTR spring Chinook Salmon. The Department leads the South Fork Trinity River snorkel survey and assists in the other tributaries. The US Forest Service (USFS) typically leads the Canyon Creek, North Fork Trinity, and New River surveys. The Hayfork Watershed Center leads the Hayfork Creek survey (Andrew Hill, CDFW, personal communication, 2020).

Data for the Klamath Tributaries from partner agencies and conservation groups can include any or all tributary creeks in both the USFS Orleans/Ukonom and the USFS Happy Camp Ranger

Districts. Reported numbers of UKTR spring Chinook Salmon in this region come exclusively from incidental sightings during the summer steelhead surveys conducted by USFS in these locations (Dan Troxel, CDFW, personal communication, 10/29/2019).

UKTR spring Chinook Salmon escapement is estimated on spawning grounds in the Upper Trinity, South Fork Trinity, and Salmon River, as well as smaller tributaries. Escapement is cooperatively estimated by a combination of tribes, agencies, and non-governmental organizations using a variety of methods including carcass surveys, weir counts, redd surveys, and mark-recapture studies (Myers et al. 1998; KRTT 2011) and at weirs by the Department, federal and tribal fishery agencies. Trap counts at both Iron Gate and Trinity River Hatcheries (shown in *Section 6.7 Hatcheries*) also contribute to overall abundance estimates. Spawning ground estimates of UKTR spring Chinook Salmon abundance can, but do not always, include both hatchery- and natural-origin spawning fish.

Similar abundance and trend metrics were calculated for UKTR fall Chinook Salmon to provide context and to help us interpret the overall abundance and trends in the combined UKTR Chinook Salmon ESU. UKTR fall Chinook Salmon population components analyzed include Bogus Creek, Mainstem Klamath River (returns to Iron Gate Hatchery omitted), Shasta River, Scott River, Salmon River, and Mainstem Trinity River (returns to Trinity River Hatchery omitted). Time series are available for these population components from about 1978 to the present with some missing years.

Time series data for both UKTR spring and fall Chinook Salmon population components prior to about 1979 are not consistently available. Therefore, available references were used to qualitatively compare current abundance and trends to those in the distant past.

Data and analyses conducted by NMFS for their original and most recent UKTR Chinook Salmon status reviews (Myers et al, 1998; Williams et al. 2011; Williams et al. 2013) were reviewed, as well as more recent data and analyses provided by scientists at NMFS Southwest Fisheries Science Center (NMFS Southwest Fisheries Science Center (SWFSC), unpublished data). Both the NMFS analyses and this status review use total adult (age > 2) spawning fish escapement estimates to characterize abundance, trends in spawning escapement, and population growth rate.

4.3.1 Abundance

4.3.1.1 Historical Abundance

Declines in salmonid abundance in the Klamath basin likely began as early as 1850 when large scale hydraulic mining was used to erode entire hillsides in search of gold. Logging in the region also increased around this time to provide building materials for gold mining operations and for building in support of a growing human population (NRC 2004).

The UKTR fall Chinook Salmon ecotype is widely distributed in the basin with upstream distribution limited by large dams. In the Klamath River drainage upstream of the Trinity River confluence, the only remaining consistent spawning aggregation of spring Chinook Salmon is in the Salmon River. Campbell and Moyle (1991) estimated annual runs ranging from 150 – 1,500 fish (but see more complete estimates in this document). In the Trinity sub-basin, a small run of spring Chinook Salmon remains in the South Fork Trinity River. A larger spawning aggregation of UKTR spring Chinook Salmon and a hatchery run exists in larger numbers in the Upper Trinity River.

Historical salmon abundance was enough to allow the Klamath River tribes to subsist largely on salmon in support of a hunter-gatherer society (Hamilton et al. 2016). Both historically and in the present day, salmon were and are a critically important cultural and nutritional foundation of Native Klamath basin tribal life.

The Department is not aware of specific quantitative assessments of historical abundance of UKTR Chinook Salmon; however, it is generally recognized that salmon runs in the Klamath basin have declined to numbers below historic levels (e.g., USDI et al. 2012; Moyle 2002). Available historical evidence (e.g., compilations by Hamilton et al. 2005; Snyder 1931; KRBFTF 1991; Lane and Lane Associates 1981) show that salmonids in the Upper Klamath basin historically contributed to large commercial, recreational, subsistence, and tribal fisheries. Likely the most important salmonid species was Chinook Salmon. Moyle (2002) estimated that UKTR spring Chinook Salmon existed at historical levels of about 100,000 spawning fish annually. The peak of UKTR Chinook Salmon (fall + spring) ESU annual abundance was estimated to be 130,000 fish based on peak cannery production of 18,000 cases of canned salmon in 1912 (Myers et al. 1998). Williams et al. (2013) note that by 1912 much of the salmonid habitat in the Upper Klamath and Trinity watersheds had been impacted by dams, mining, and other land- and water-use disturbances, suggesting that the peak historical run size above might be an underestimate. As of about 1963, the Department estimated the annual spawning escapement of UKTR spring and fall Chinook Salmon to comprise approximately 88,000 adults in the Klamath River and 80,000 adults in the Trinity River (total 168,000 adults annually; CDFG 1965). Studies by USFWS/CDFG (1956) estimated that 3,000 UKTR spring Chinook Salmon and 8,000 UKTR fall Chinook Salmon adult migrants historically passed above Lewiston Dam on the Trinity River. Some rough estimates (e.g., Moyle et al. 2017) estimate that current UKTR spring Chinook Salmon total numbers are far less than their historic abundance.

4.3.1.2 Time Series of Abundance

Raw counts of total UKTR spring Chinook Salmon returns since about 1978 are shown in Figures 4.1, 4.2, 4.3, 4.4 and 4.5. As is characteristic of salmon populations, annual variation in abundance is high and cyclic which complicates abundance and trend evaluations. Estimates of trends in abundance can be affected by where in the cycle the evaluation begins and ends. Beginning at a peak and ending at a trough will generally indicate decline, whereas starting at a trough and ending at a peak will generally result in a conclusion of population growth. To partially account for this, this analysis uses a variety of methods over long-, medium-, and short-time frames to characterize abundance status and trends. The Department has collected a relatively long time-series of data for several extant UKTR spring and fall Chinook Salmon population components.

The Trinity River Restoration Program (TRRP) sets an annual target of 6,000 naturally produced adult spawning UKTR spring Chinook Salmon system-wide. In the last five years, the TRRP goal was not met 60% of the time (Figure 4.2, 3 of 5 years). Of the remaining two years, this goal was barely met or exceeded. This contrasts with the long-term (2002 – 2018) abundance in which the goal was not met about 24% of the time. Recent UKTR spring Chinook Salmon escapement has been under the TRRP goal more frequently than in the past. In comparison, UKTR fall Chinook Salmon numbers in areas where UKTR spring Chinook Salmon also occur are much larger than those for UKTR spring Chinook Salmon alone between 1978 and the present (Figure 4.4). Larger UKTR fall Chinook Salmon abundance results in relatively robust raw numbers of the combined UKTR Chinook Salmon ESU over the monitoring period.

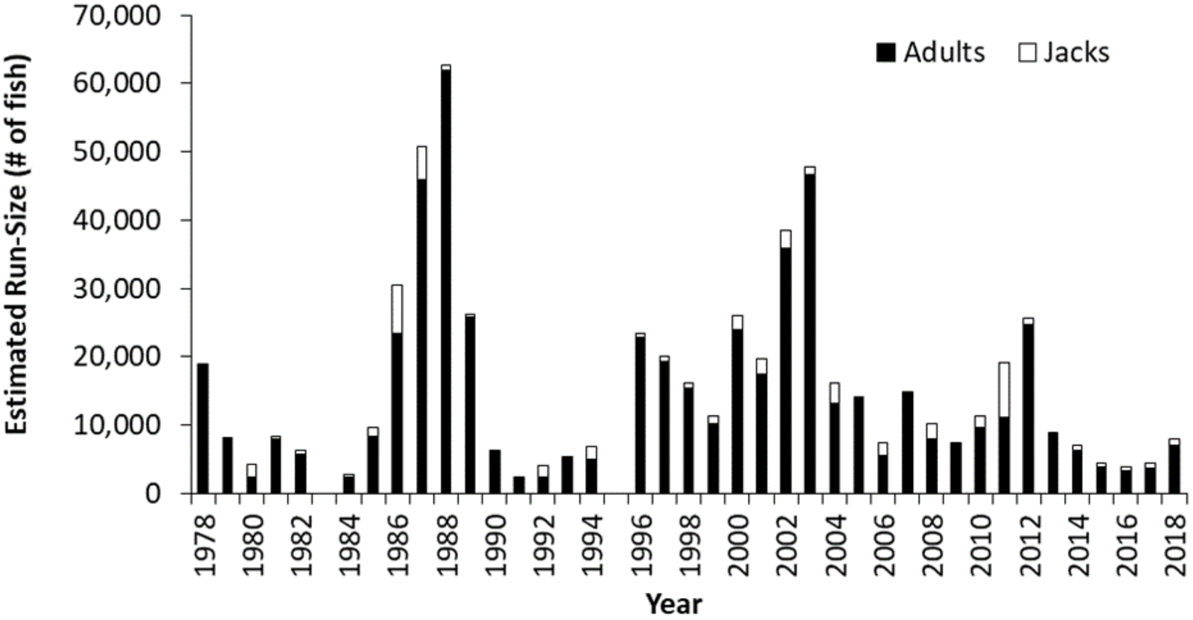

Figure 4.1. UKTR spring Chinook Salmon counts from the Upper Trinity River above Junction City Weir showing number of adults and jacks in each year. Estimates based on mark/recapture surveys. Estimates include hatchery-origin natural area spawning fish and hatchery-origin fish bound for Trinity River Hatchery.

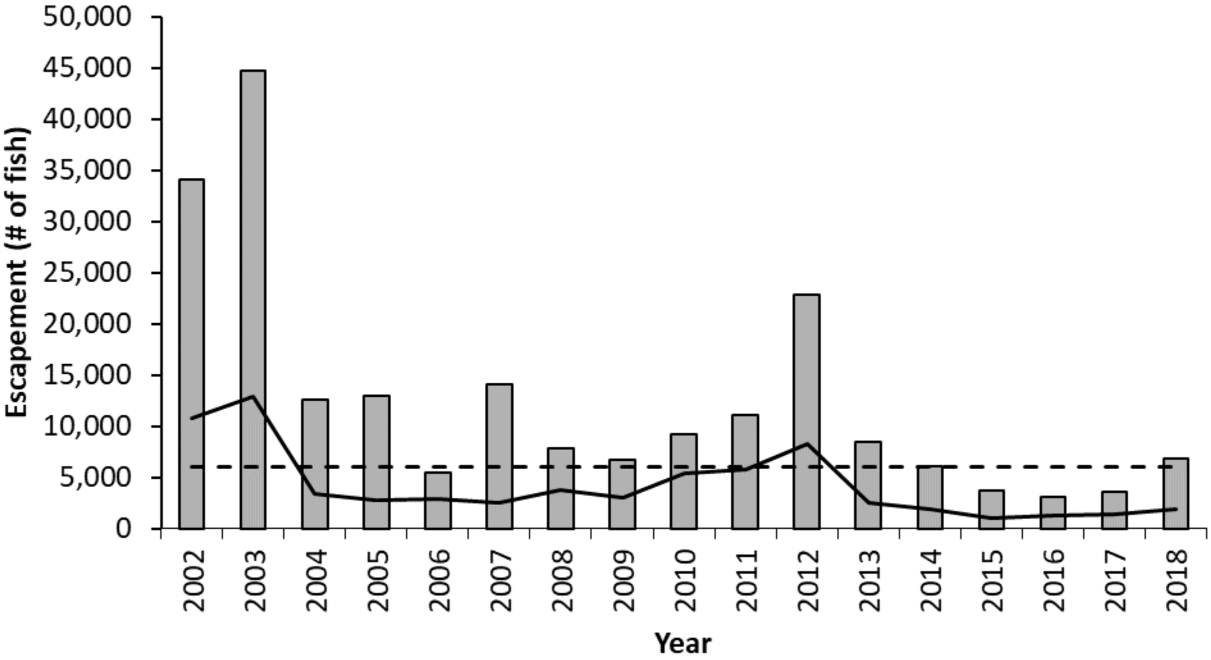

Figure 4.2. UKTR spring Chinook Salmon adult abundance for the Upper Trinity River above Junction City Weir. Solid line indicates natural origin adult estimates. Dashed line indicates Trinity River Restoration Program abundance goal of 6,000 annual spawning fish.

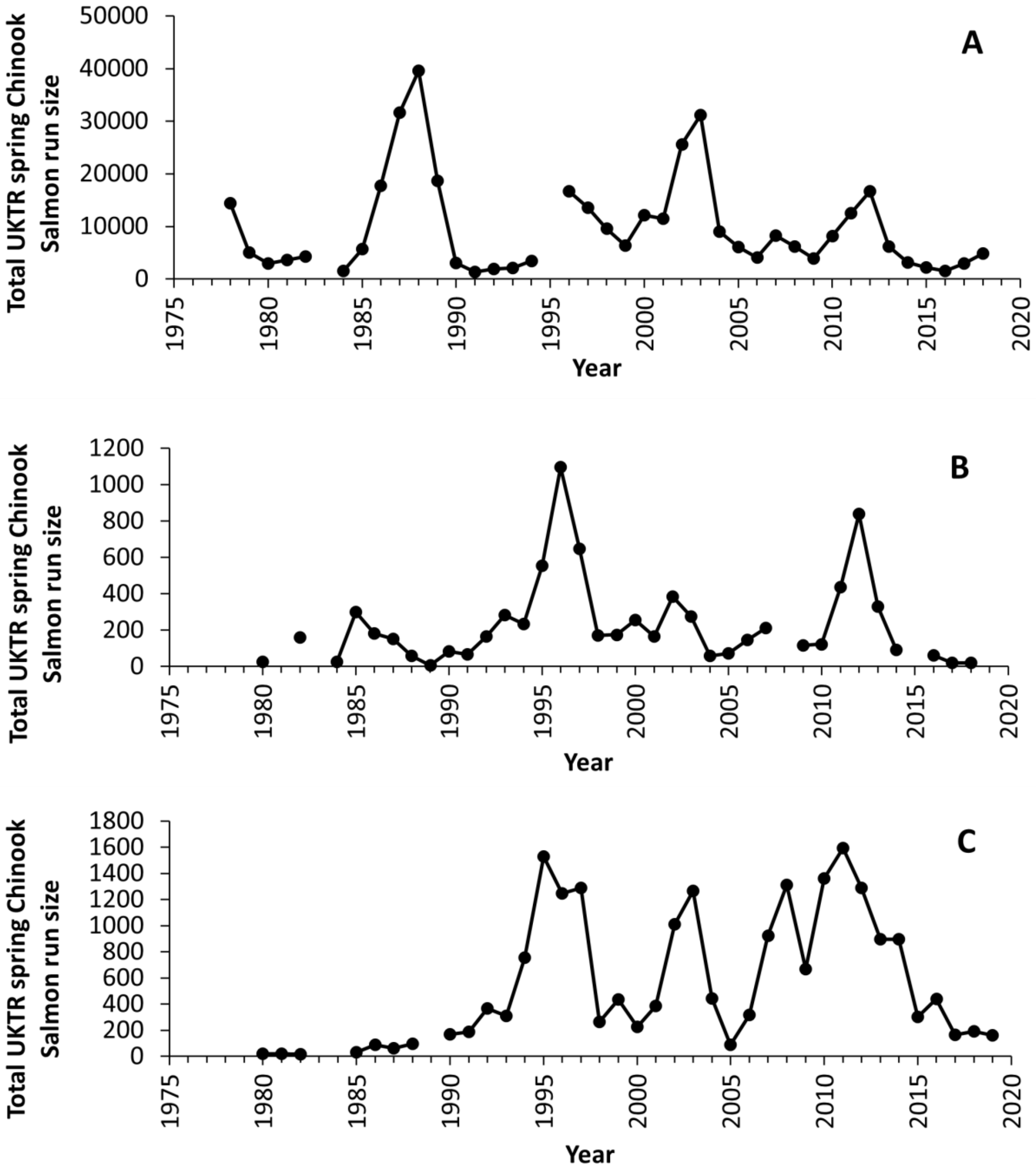

Figure 4.3. Total run-size estimates for UKTR spring Chinook Salmon population components. A. Upper Trinity River above Junction City Weir B. Salmon River, C. South Fork Trinity River. Note different scales on the Y-axes.

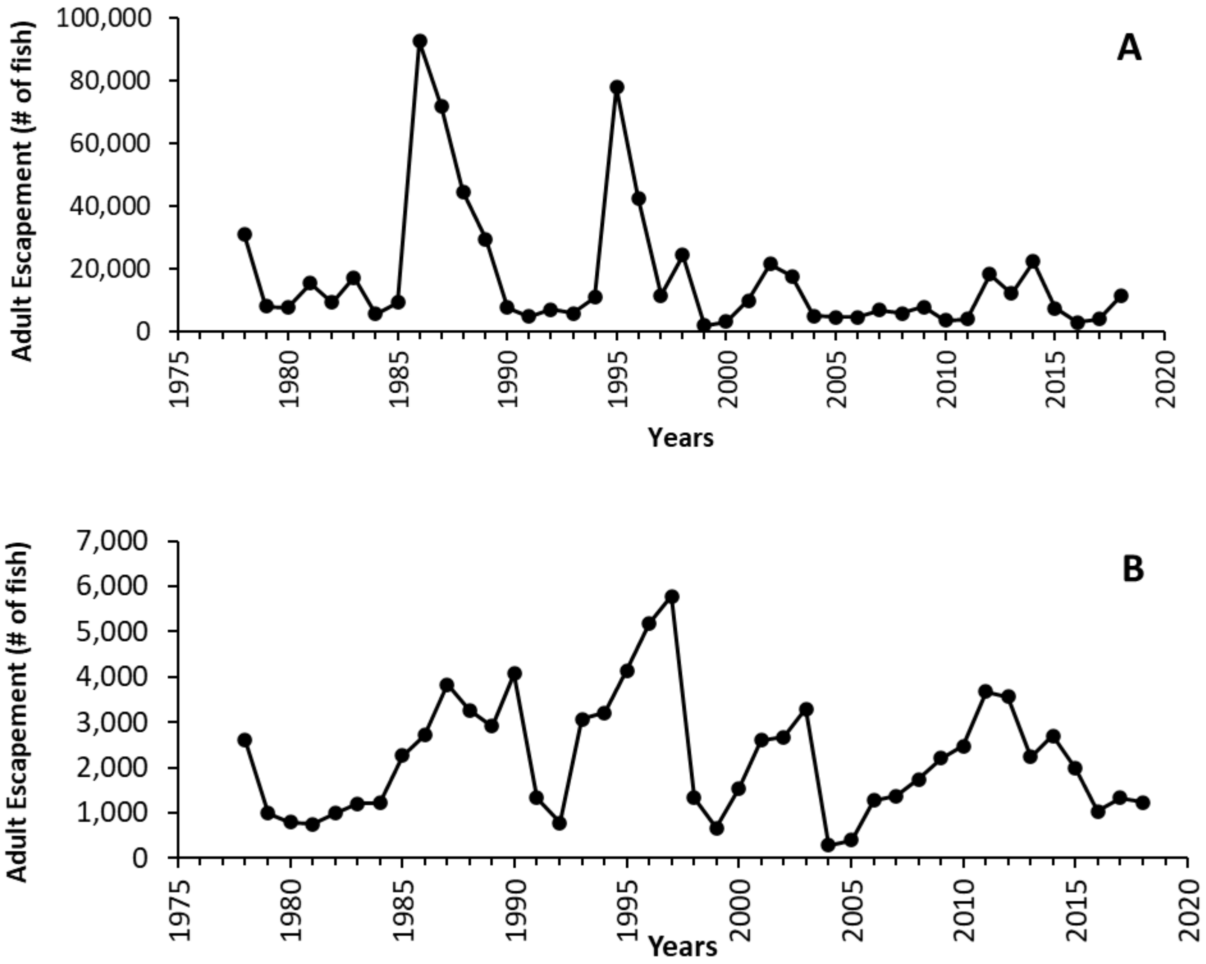

Figure 4.4. Adult escapement estimates for UKTR fall Chinook Salmon population components in A: Upper Trinity River above Willow Creek, excluding returns to Trinity River Hatchery, B: Salmon River. Note different y-axis scales.

4.3.1.3 Geometric Mean Abundance

The Department evaluated status using the best available long-term data sets. However, the Department realizes that what amounts to “historical abundance” based on records from several decades ago, while useful for evaluating status and trend over that period, may have limited use for predicting future abundance. Past escapement estimates may be less useful than recent estimates to predict current and future escapement (e.g., see *Sections 6.1 Climate Change and Potential impacts* and *7.1 Klamath Dam Removal*). For this reason, the following analysis presents long-term estimates using all data available to us while relying on more recent 12- and five-year geometric means as the best indicators of current abundance status. UKTR spring Chinook Salmon declines prior to approximately 1978 – 1980 are not reflected in the analyses below.

Because UKTR spring and fall Chinook Salmon are not reproductively isolated, and any spawning pair may have offspring with either fall or spring life history (see Genetics and Genomics), calculations of average abundance and trend by ecotype are subject to error. Although some of the following analyses attempt to correct for this, contributions of fall Chinook to spring Chinook numbers and trends, and vice versa, are not fully accounted for in the following analyses.

Table 4.1 shows minimum and maximum abundance estimates for the three UKTR spring Chinook Salmon population components over three time-frames—short, medium, and long. The South Fork Trinity River has the lowest values, followed by Salmon River. The Upper Trinity River minimum and maximum are moderately large; however, all maxima and minima in the short time frame are smaller than in either the medium or long-time frames. This suggests that current abundance is low in relation to past (about 30 years ago) abundance. Whether this represents a low point in the population component cycle or a new low average is not known.

Table 4.1. Minimum and maximum abundance at long-term, short-term, and medium-term time windows for the three UKTR spring Chinook Salmon population components

	Upper Trinity River	Salmon River	SF Trinity River
Long-term Years	1978-2018	1995-2018	1980-2019
Long-term min	942	78	7
Long-term max	39,329	1,335	1,097
5-year Years	2014-2018	2015-2019	2014-2018
5-year min	1,331	133	17
5-year max	4,352	406	83
12-year Years	2007-2018	2008-2019	2007-2018
12-year min	1,331	133	17
12-year max	16,117	1,242	779

The Department evaluated abundance status using the geometric mean over long-term, using the longest running time-series available, medium-term, using data for the last four generations (12-years), and recent, using the last five years of available data, for each of the UKTR spring and fall Chinook Salmon population components. There were missing data in some of the time series noted in the following tables. Only the available data were used in the calculations, with no effort to interpolate or otherwise fill in missing data.

The geometric mean was calculated as follows:

$$\bar{G} = \sqrt[n]{N_1 x\ N_2 x\ N_3 x\ N_{4\ \ldots} x\ N_n}$$

Geometric mean is a useful metric for status evaluation because it calculates central tendency of abundance while minimizing the effect of outliers in the data and is thought to more effectively characterize time series of abundance based on counts than the arithmetic average. The arithmetic average is known to be overly sensitive to a few large counts and can result in an incorrect depiction of central tendency with typically highly variable salmon population data.

In most cases, the long-term geometric mean abundance for UKTR spring Chinook Salmon spawning assemblages was greater than 12-year estimates (Tables 4.1, 4.2). The exception is the Salmon River, for which the most recent 12-year average abundance is about the same as the long-term (LT) average (LT 479, 12-yr 485). The geometric mean abundance for Upper Trinity River Springs was greatest with over 5,000 fish per year in long-term estimates and over 2,000 fish per year in recent ones (5-year averages). Salmon River spring Chinook had a long-term annual average in the hundreds (just below 500), and a recent average around 200. The South Fork Trinity River abundance comes in lowest with annual averages around 120 and recent 5-year averages below 50.

Table 4.2. Long-, medium-, and short-term geometric mean abundance for the three UKTR spring Chinook Salmon population components.

Population component	Years	Long-term Geometric mean	Years	12-year Geometric mean	Years	5-year Geometric mean
Upper Trinity River	1978-2018[1]	5,727	2007-2018	4,394	2014-2018	2,404
Salmon River	1995-2018[2]	479	2008-2019	485	2015-2019	203
South Fork Trinity River	1980-2018[3]	126	2007-2019	106	2014-2018	34

[1]missing data 1983, 1995

[2]missing data 1996, 1998

[3]missing data 1981, 1983, 2008, 2015

UKTR spring Chinook Salmon are also found in small numbers in both Klamath and Trinity River tributaries (Table 4.3). As can be seen in the table, these counts are incomplete over the time series. This analysis used the entire data set to calculate long-term geometric mean. Due to missing data for some years, data from the last 15 years were used (five 3-yr generations) rather than our preferred 12 years (four 3-year generations) to calculate recent geometric mean (status) to include at least 10 data points in the calculation. The long-term (1980 – present) geometric mean for adult spawning fish in Klamath tributaries is very low (a few fish), and a little higher in the Trinity tributaries (tens of fish). The recent geometric mean for the Klamath tributaries is similarly very low; however, the recent geometric mean for the Trinity tributaries is a somewhat higher at 50 (adults) and 71 (adults and grilse). This may be due to hatchery fish straying into otherwise small aggregations of naturally spawning fish. UKTR spring Chinook Salmon in the miscellaneous Klamath and Trinity River tributaries contribute little to the overall numbers of UKTR spring Chinook Salmon in the basin; however, their persistent presence represents a minor part of the total range of the UKTR spring Chinook Salmon ecotype, demonstrates distribution of the spring ecotype outside of the three known spawning assemblages, and shows potential for metapopulation expansion.

Abundance of the UKTR fall Chinook Salmon ecotype was calculated for six spawning locations in the Klamath and Trinity Rivers (Tables 4.4, 4.5). The range of abundance estimates for the fall ecotype is large, ranging from hundreds to tens of thousands of fish in all time frames in all locations. Large maxima (tens of thousands) are found in the mainstem Klamath, Trinity, Scott, and Shasta rivers. Maximum fall ecotype abundance is lower (thousands of fish) in the Salmon River.

Table 4.3. Escapement of UKTR spring Chinook Salmon to miscellaneous Klamath and Trinity river tributaries, 1980 – 2019. Long-term geometric mean uses the entire data set. Recent geometric mean uses the last 5-generations (3-year generation time; 15 years) to include at least 10 data points in the calculation.

Year	Klamath Tributaries Grilse	Klamath Tributaries Adults	Klamath Tributaries Total	Klamath Tributaries Grilse prop	Trinity Tributaries Grilse	Trinity Tributaries Adults	Trinity Tributaries Total	Trinity Tributaries Grilse prop
1980						49	49	0.00
1981		4	4	0.00				
1982		5	5	0.00		8	8	0.00
1983		6	6	0.00		39	39	0.00
1984		16	16	0.00		25	25	0.00
1985		5	5	0.00		29	29	0.00
1986								
1987		2	2	0.00				
1988		8	8	0.00		273	273	0.00
1989		9	9	0.00			17	0.00
1990							33	0.00
1991							5	0.00
1992						15	18	0.17
1993							48	0.00
1994		1	1	0.00			22	0.00
1995		2	2	0.00			135	0.00
1996		2	2	0.00			73	0.00
1997							49	0.00
1998		2	2	0.00			33	0.00
1999		14	14	0.00			15	0.00
2000		6	6	0.00		16	16	0.00
2001	1	1	2	0.50	2	6	8	0.25

Year	Klamath Tributaries Grilse	Klamath Tributaries Adults	Klamath Tributaries Total	Klamath Tributaries Grilse prop	Trinity Tributaries Grilse	Trinity Tributaries Adults	Trinity Tributaries Total	Trinity Tributaries Grilse prop
2002	2	2	4	0.50	10	16	26	0.38
2003		1	1	0.00	1	83	84	0.01
2004	1	2	3	0.33	5	12	17	0.29
2005	1	8	9	0.11	2	4	6	0.33
2006		1	1	0.00	42	70	112	0.38
2007					4	54	58	0.07
2008	2	5	7	0.29	5	23	28	0.18
2009	0	3	3	0.00	47	46	93	0.51
2010	0	3	3	0.00	50	180	230	0.22
2011	23	82	105	0.22	199	361	560	0.36
2012	2		2	1.00	69	358	427	0.16
2013	5	13	18	0.28	58	166	224	0.26
2014		21	21	0.00	27	105	132	0.20
2015		7	7	0.00				
2016					6	42	48	0.13
2017		2	2	0.00	2	32	34	0.06
2018	1	11	12	0.08	11	6	17	0.65
2019								
Totals	**38**	**244**	**282**		**543**	**2018**	**2991**	
Geometric mean-Long-term		**4**	**5**			**38**	**42**	
Geometric mean- Recent		**6**	**6**			**50**	**71**	

Geometric mean abundance for the fall ecotype in all monitored locations is in the thousands to tens of thousands over all time frames (Table 4.4). The recent 5-year geometric mean is less than the long and 12-year estimates in Mainstem Trinity, Salmon, Scott rivers, and Bogus Creek. However, recent geometric mean abundance in the Shasta and Mainstem Klamath are greater than or about the same as the long- and medium-term estimates. Recent geometric means for UKTR fall Chinook Salmon are relatively large (1,500 to over 8,000), indicating low risk of immediate extinction of either the fall ecotype or the combined UKTR Chinook Salmon ESU due to population size.

Table 4.4 Minimum and maximum adult (>2-year old) abundance at long-term, short-term, and medium-term time windows for six UKTR fall Chinook Salmon population components.

	Mainstem Trinity R.[1]	**Salmon River**	**Scott River**	**Shasta River**	**Bogus Creek**	**Mainstem Klamath R.[2]**
Long-term Years	1978-2018	1978-2018	1978-2018	1978-2018	1978-2018	1978-2018
Long-term Min	3,444	282	445	213	598	366
Long-term Max	92,548	5,783	11,988	27,600	45,225	22,443
5-year Years	2014-2018	2014-2018	2014-2018	2014-2018	2014-2018	2014-2018
5-year Min	3,444	1,032	1,208	2,754	830	2,902
5-year Max	23,312	2,706	10,419	18,673	12,607	22,443
12-year Years	2007-2018	2007-2018	2007-2018	2007-2018	2007-2018	2007-2018
12-year Min	3,444	1,032	1,208	213	830	2,902
12-year Max	47,921	3,674	10,419	27,600	12,607	22,443

[1] Excluding Trinity River Hatchery returns

[2] Excluding Iron Gate Hatchery returns

Table 4.5. Long-, medium-, and short-term geometric mean adult (>2-year old) abundance for six UKTR fall Chinook Salmon population components.

Population component	Years	Long-term Geo. Mean	Years	12-year Geo. Mean	Years	5-year Geo. Mean
Mainstem Trinity River[1]	1978-2018	16,134	2007-2018	15,512	2014-2018	8,149
Salmon River	1978-2018	1,817	2007-2018	1,974	2014-2018	1,554
Scott River	1978-2018	3,252	2007-2018	3,003	2014-2018	2,415
Shasta River	1978-2018	3,085	2007-2018	4,174	2014-2018	6,941
Bogus Creek	1978-2018	4,706	2007-2018	3,608	2014-2018	2,751
Mainstem Klamath River[2]	1978-2018	3,220	2007-2018	7,285	2014-2018	7,364

[1] Excluding Trinity River Hatchery returns

[2] Excluding Iron Gate Hatchery returns

Kinziger et al. (2013) found three genetic groups of Chinook Salmon in the Klamath-Trinity: Lower River, Klamath, and Trinity groups. Of these, the Klamath Group and the Trinity Group are within the UKTR Chinook Salmon ESU. A rough estimate of the geometric mean abundance for these two groups was calculated by combining existing abundance data for both UKTR spring and fall Chinook Salmon population components in the geographic areas defined by the genetic groupings (Table 4.6).

Based on the combined abundance of UKTR Chinook Salmon in these two genetic groups, the Department's analysis found large geometric mean abundances in all time frames. This was due to the large fall ecotype component. Geometric means for both genetic groups were in the tens of thousands suggesting low risk of immediate extinction of these two groups.

Table 4.6. Long-, medium-, and short-term geometric mean adult (>2-year old) abundance for two of three UKTR Chinook Salmon genetic population groups.

Genetic Population Group	Years	Long-term Geo. mean	Years	12-year Geo. mean	Years	5-year Geo. Mean
Trinity River Group[1]	1978-2018	22,719	2007-2018	20,289	2014-2018	10,812
Klamath River Group[2]	1978-2018	19,456	2007-2018	22,978	2014-2018	22,422

[1] Trinity River Group includes: Mainstem Trinity River fall (excluding TRH returns), SF Trinity River spring, Trinity River Tributaries spring, Upper Trinity River spring above Junction City Weir.
[2] Klamath River Group includes: Mainstem Klamath River fall (excluding IGH returns), Salmon River spring and fall, Scott River fall, Shasta River fall, Bogus Creek fall, Klamath River Tributaries spring.

4.3.2 Trends in Abundance

The Department evaluated trends in abundance by calculating the slope of annual abundance over time following methods in Good et al. (2005) and Williams et al. (2011, 2013), with some modification. The Department estimated trends for all UKTR Chinook Salmon population components for which data are available using adult returns (age >2) only. The adult escapement abundance reflects trends in cohort strength of natural area spawning fish and natural area productivity. The adult escapement evaluation shows natural area return of the most productive element of the population component. Jacks, harvest, and spawning fish that return to the hatchery are not included in the following calculations. This group, however, does include hatchery-origin fish that return to natural spawning grounds. Hatchery- and natural-origin natural spawning ground returns are only estimated separately at the Junction City Weir for the Upper Trinity River population component.

Abundance trends were calculated for the three extant UKTR spring Chinook Salmon population components (Upper Trinity River above Junction City Weir, Salmon River, and South Fork Trinity River), and for six UKTR fall Chinook Salmon population components in the basin. Long-term trends were evaluated using all adult natural area return data in the available time series for each population component. The recent trend was evaluated using estimates of the annual number of natural area spawning fish for the last four Chinook Salmon generations (i.e., 12 years assuming an average 3-year generation length) with a minimum of ten data points in the series. This analysis uses four generations to calculate “recent” trend because it is close enough to the present to reflect population-level responses to current conditions while still providing enough data points (at least 10 over the 12-year period) to characterize the trend[8].

The Department estimated the trend as the calculated slope of the number of natural spawning adults over time using a linear regression performed on natural log-transformed annual counts over the time series:

$$ln(N_t) = \beta_0 + \beta_1 X + \in$$

Where N_t is natural area adult spawning fish abundance, β_0 is the y-intercept, β_1 is the slope of the equation, and ε is a random error term. If necessary, one was added to all annual population size estimates prior to transformation [i.e., $ln(N_t + 1)$] to account for zeros (i.e., years in which a location *was surveyed* but no fish were found there) in the data. Missing data (i.e., years in which a location *was not surveyed*) were accounted for in the regression analysis using multiple imputation (Horton and Kleiman 2007)[9].

Trend over the time series was expressed as exponentiated slope from the regression above:

$$\exp(\widehat{\beta_\iota})$$

with 95% confidence intervals:

$$\exp(\hat{\beta}_i) \pm t_{0.025,df}\ x\ se$$

Table 4.7 shows long-term and recent trends for the three extant UKTR spring Chinook Salmon population components. Trend values less than one indicate a decline of the average population component, whereas trend values greater than one indicate average growth. Recent adult trends for all UKTR spring Chinook Salmon population components are below one indicating across the board recent average declines in the three UKTR spring Chinook Salmon population components; however, confidence intervals for these estimates are large and, in most cases, inconclusive. Confidence intervals for recent Salmon and South Fork Trinity rivers spring Chinook Salmon support a conclusion of decline, whereas those for Upper Trinity River

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[8] The federal Biological Review Team in its evaluation of abundance trend expressed caution about short (recent) time series estimates due to the small number of data points in these estimates (Williams et al. 2013).

[9] Williams et al. (2013) dealt with missing data in trend regressions by simply omitting missing data years. In a limited evaluation of the two methods for this report (not shown) the two methods gave similar, though not identical numerical results; however, the trend direction and significance were the same regardless of the method used to account for missing data.

spring Chinook Salmon do not. The Department concludes that the UKTR spring Chinook Salmon ecotype in the Salmon River and South Fork Trinity River have likely declined in recent years.

Long term population component trends for UKTR spring Chinook Salmon show similar average declines but the trend is not supported by confidence intervals (Table 4.7).

Table 4.7. Long-term and recent trends in adult abundance (escapement) using slope of *ln*-transformed times series counts for three UKTR spring Chinook Salmon population components. Trend estimates >1 indicate average population increase over the time series, whereas those <1 indicate average decline. Long-term trends use the entire time series available for that group. Recent trends use the last 12 years (four generations) with at least 10 data points. Missing data were accounted for in the regression by multiple imputation. All escapement is adults only.

Population component	Long-term spring Years	Long-term spring Trend	Long-term spring Lower 95% CI	Long-term spring Upper 95% CI	Recent spring Years	Recent spring Trend	Recent spring Lower 95% CI	Recent spring Upper 95% CI
Upper Trinity River above JCW[1]	1978-2018	0.9968	0.9713	1.0230	2007-2018	0.9020	0.8052	1.0104
Salmon River[2]	1995-2019	0.9709	0.9051	1.0415	2008-2019	0.8227	0.7513	0.9010
SF Trinity River[3]	1980-2018	0.9806	0.9458	1.0166	2008-2019	0.7440	0.6102	0.9072

[1] JCW = Junction City Weir. Missing data Long-term 1983, 1995

[2] Missing data long-term 1996, 1998

[3] Missing data long-term 1981, 1983, 2008, 2015; recent 2008, 2015

Average UKTR fall Chinook Salmon long- and recent-term trends (Table 4.8) for adult returns to six locations where long-term monitoring has generated annual estimates since 1978 were also calculated. Long-term average trends were less than one (declining) for fall Chinook Salmon in the Mainstem Trinity River, Scott River, and Bogus Creek. Average long-term trends were greater than one (increasing) in the Salmon River, Shasta River, and Mainstem Klamath River. However, confidence intervals for all but the Mainstem Klamath River fall Chinook Salmon range from below to above one, indicating lack of statistical support for the average trends in these population components. The trend analysis for Mainstem Klamath River fall Chinook Salmon do show statistical support for the increasing trend in this group.

Table 4.8. Long-term and recent trends in adult (>2-year old) abundance using slope of ln-transformed times series counts for six UKTR fall Chinook Salmon population components. Trend estimates >1 indicate average population increase, whereas those <1 indicate average decline. Long-term trends use the entire time series available for that group. Recent trends use the last 12 years (4 generations) with at least 10 data points. All escapement is adults only.

Population component	Long-term fall Years	Long-term fall Trend	Long-term fall Lower 95% CI	Long-term fall Upper 95% CI	Recent fall Years	Recent fall Trend	Recent fall Lower 95% CI	Recent fall Upper 95% CI
Mainstem Trinity River[1]	1978-2018	0.9977	0.9757	1.0203	2007-2018	0.8851	0.7695	1.0181
Salmon River	1978-2018	1.0014	0.9830	1.0200	2007-2018	0.9606	0.8911	1.0355
Scott River	1978-2018	0.9940	0.9745	1.0138	2007-2018	0.9378	0.8341	1.0545
Shasta River	1978-2018	1.0057	0.9770	1.0352	2007-2018	1.1505	0.9063	1.4603
Bogus Creek	1978-2018	0.9997	0.9747	1.0254	2007-2018	0.9356	0.8153	1.0736
Mainstem Klamath River[2]	1978-2018	1.0580	1.0341	1.0824	2007-2018	1.0114	0.8902	1.1491

[1] Excluding Trinity River Hatchery

[2] Excluding Iron Gate Hatchery

Recent fall Chinook Salmon population component trends showed average declines in the Mainstem Trinity River, Salmon River, Scott River, and Bogus Creek. A recent increasing average trend was observed in UKTR fall Chinook Salmon returning to the Shasta River and the Mainstem Klamath River; however, there was no statistical support for any of these recent average trends.

Lastly, Kinziger et al. (2013) found three genetically defined groups of Chinook Salmon in the Klamath-Trinity basin: Klamath River, Trinity River, and Lower River. Of these, the Klamath and Trinity river groups are within the geographic boundaries of the UKTR Chinook Salmon ESU. The Lower River group is included in the Southern Oregon and Coastal Chinook Salmon ESU and, therefore, is not a part of this review.

Because the UKTR spring Chinook Salmon are an ecotype of the larger UKTR Chinook Salmon ESU, the Department calculated trends for these two more inclusive genetically defined groups (Table 4.9). To do this, the estimated number of annual UKTR spring and fall Chinook Salmon from each location where monitoring is conducted were added together. Adding the available data in this way is not ideal because it does not account for intrinsic sampling bias or differences in sampling method or period; however, it is the only option for evaluating the combined spring and fall ecotype components as genetically defined units with the available data.

When treated as two separate populations, the trend for the Trinity River Group was less than one (declining) and that for the Klamath River Group was greater than one (increasing) over both the long term and recent monitoring periods; however, as in other sections of this analysis, there was no statistical support for either trend.

Table 4.9. Long-term and recent trends in adult (>2-year old) abundance using slope of *ln*-transformed times series counts for the two UKTR Chinook Salmon genetic population groups (combined spring and fall; Kinziger et al. 2013). Trend estimates >1 indicate average population increase, whereas those <1 indicate average decline. Long-term trends use the entire time-series available for that group. Recent trends use the last 12 years (4 generations) with at least 10 data points. All escapement is adults only.

Genetic Population Group	Long-term Years	Long-term Trend	Long-term Lower 95% CI	Long-term Upper 95% CI	Recent Years	Recent Trend	Recent Lower 95% CI	Recent Upper 95% CI
Trinity River Group[1]	1978-2018	0.9978	0.9759	1.0202	2007-2018	0.8894	0.7798	1.0144
Klamath River Group[2]	1978-2018	1.0141	0.9961	1.0325	2007-2018	1.0076	0.8926	1.1374

[1] Trinity River Group includes: Mainstem Trinity River fall (excluding TRH returns), SF Trinity River spring, Trinity River Tributaries spring, Upper Trinity River spring above Junction City Weir.

[2] Klamath River Group includes: Mainstem Klamath River fall (excluding IGH returns), Salmon River spring and fall, Scott River fall, Shasta River fall, Bogus Creek fall, Klamath River Tributaries spring.

4.5.3 Productivity

The Department evaluated productivity of the UKTR spring and fall Chinook Salmon population components by evaluating cohort replacement rate over time. Cohort Replacement Rate (CRR) expressed as *ln*(CRR) was:

$$ln\ (CRR) = ln\left(\frac{N_{t+3}}{N_t}\right)$$

Natural log transformed CRRs > 0 indicate that the cohort increased in size that year in relation to the brood year three years earlier, whereas *ln*(CRR) < 0 indicates that it declined over that generation. This analysis assumes a three-year generation time for UKTR Chinook Salmon. The analysis used adults only for the CRR calculations to better meet the three-year generation time assumption. Gaps in the graphs below are due to years without data (Figures 4.5, 4.6, 4.7).

For the entire available time series, *ln*-CRRs for the three UKTR spring Chinook Salmon population components show about as many “less than replacement” as “greater than replacement” years (Figure 4.5). However, looking at recent years, the Salmon River population component exhibits *ln*-CRRs below zero from 2013 – 2019 spawning years. Both Upper Trinity River and South Fork Trinity River population components show declines in recent years, but an upturn was noted in 2019, which might be expected given the cyclic nature of the long-term trend.

Cohort replacement rates for UKTR fall Chinook Salmon show a similar pattern of growth and decline years in cyclic clusters (Figures 4.6, 4.7). Over the entire time series (about 1980 – 2019), there are approximately the same number of positive as negative *ln*(CRR)s for all fall population components. Recent years are in a decline phase that lasts between about 2013 – 2017. This is similar to the *ln*(CRR) pattern observed in the UKTR spring Chinook Salmon population components, suggesting that the spring and fall elements are experiencing similar environmental conditions and responding similarly to them. Drought conditions across California 2014 – 2017 are correlated with these low *ln*(CRR)s. Cohort replacement rates for four of the six fall population components show increases in 2018 or 2019. This pattern of a decline phase of about 2 – 5 years followed by an increase phase for several years is a typical pattern for anadromous salmonid populations. The most recent year *ln*(CRR) for Salmon and Scott River fall Chinook Salmon continues the decline phase, unlike other fall population components. It is unknown whether less than replacement *ln*(CRR)s will continue in the future, or whether they will show delayed improvement as in the previous pattern.

Overall, both UKTR fall Chinook Salmon and UKTR spring Chinook Salmon population components show similar patterns of cohort replacement rates. They show similar cycles of positive and negative values in most cases. Recent *ln*(CRR)s for all population components are “less than replacement” with an upturn in 2018 – 2019 in most cases. The Salmon River UKTR spring Chinook Salmon population component remains below replacement.

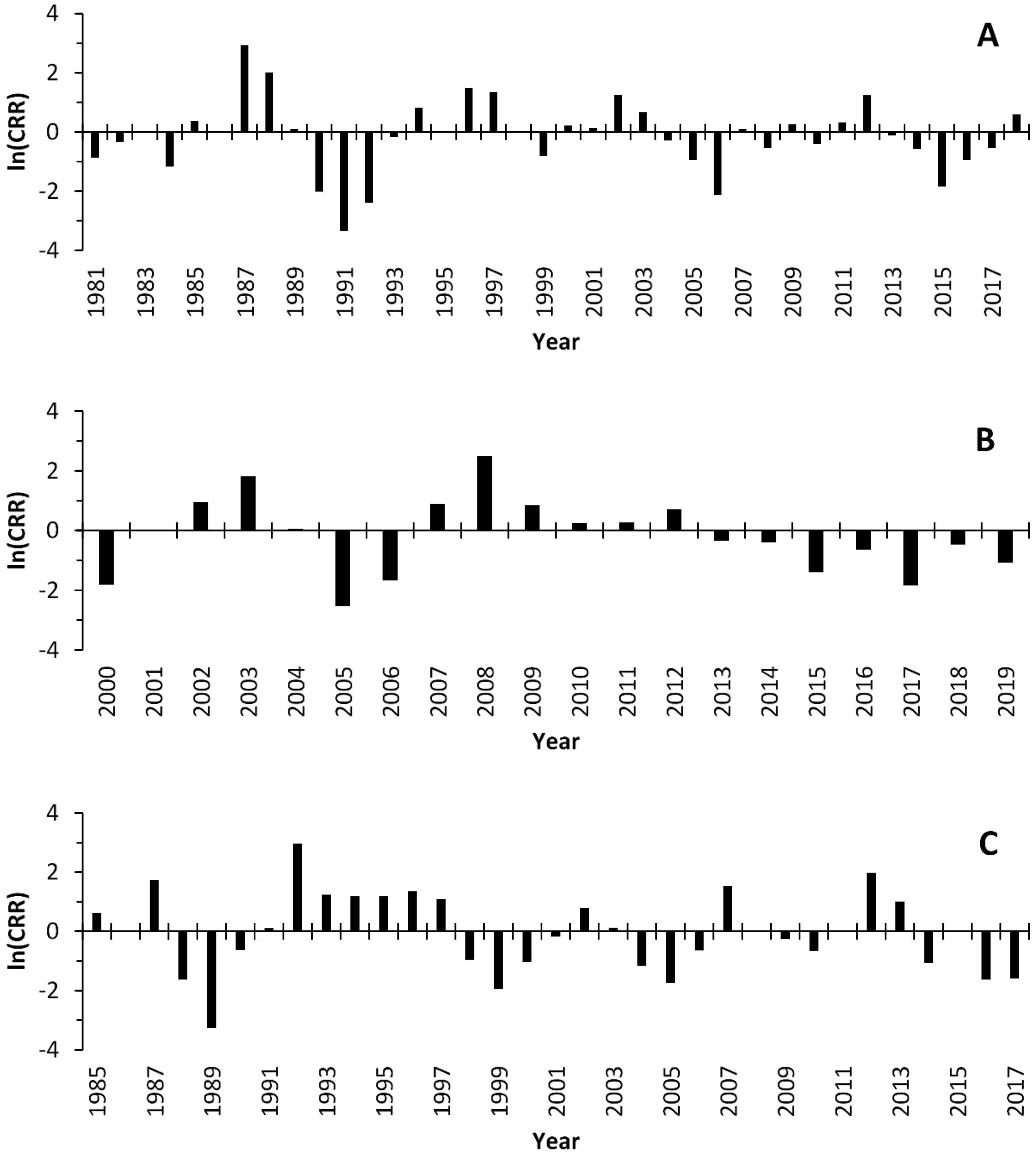

Figure 4.5. Natural log-transformed Cohort Replacement Rates (*ln*CRR) for the three UKTR spring Chinook Salmon population components of UKTR Chinook Salmon ESU: A) Upper Trinity River, B) Salmon River, and C) South Fork Trinity River. Data are adult natural area spawning fish only. Differing X-axis ranges and gaps are due to years with missing data.

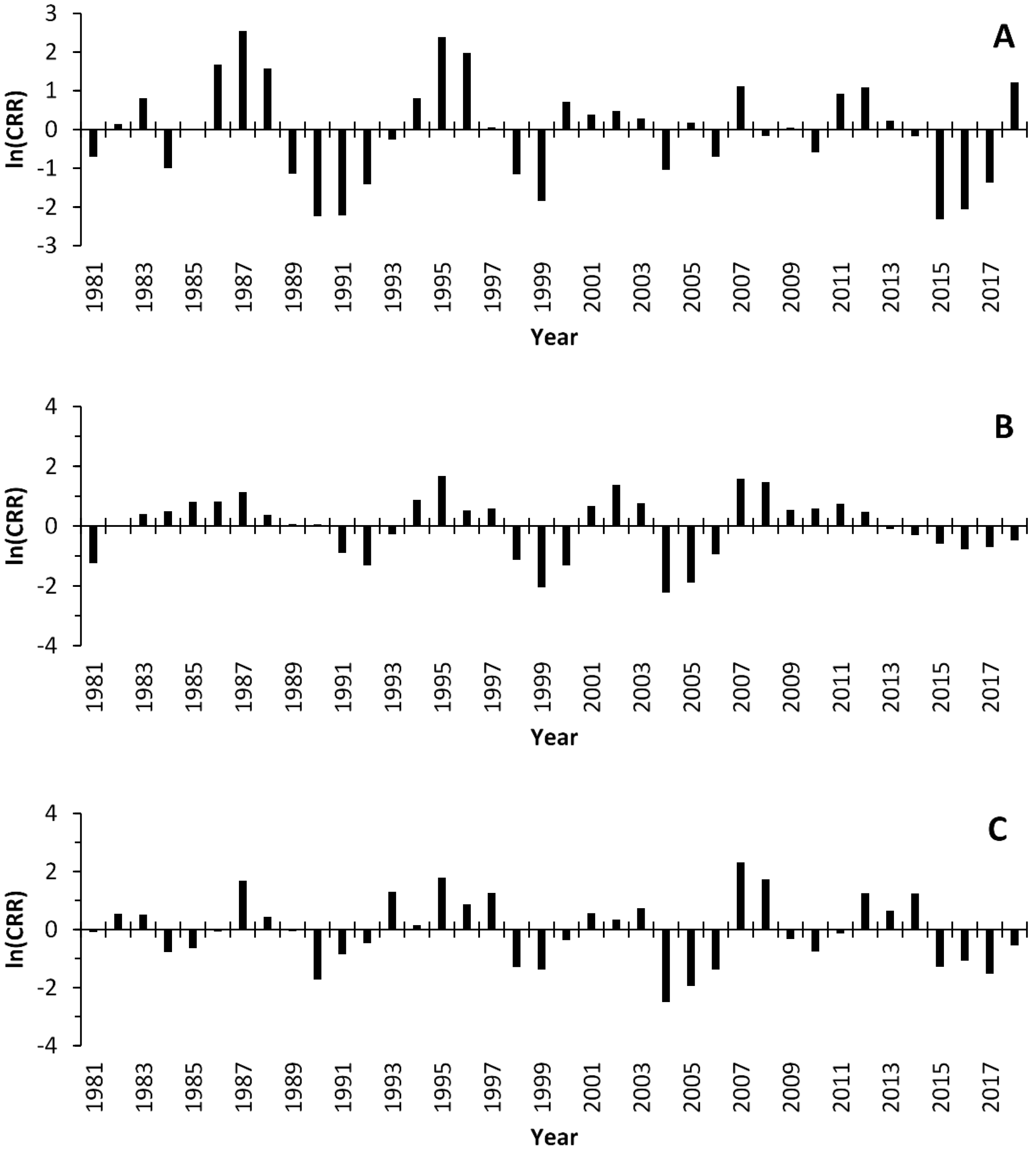

Figure 4.6. Natural log-transformed Cohort Replacement Rates (*ln*CRR) for three fall population components of UKTR Chinook Salmon ESU: A) Mainstem Trinity River (excluding Trinity River Hatchery returns), B) Salmon River, C) Scott River. Data are adult natural area spawning fish only. Gaps are due to years with missing data.

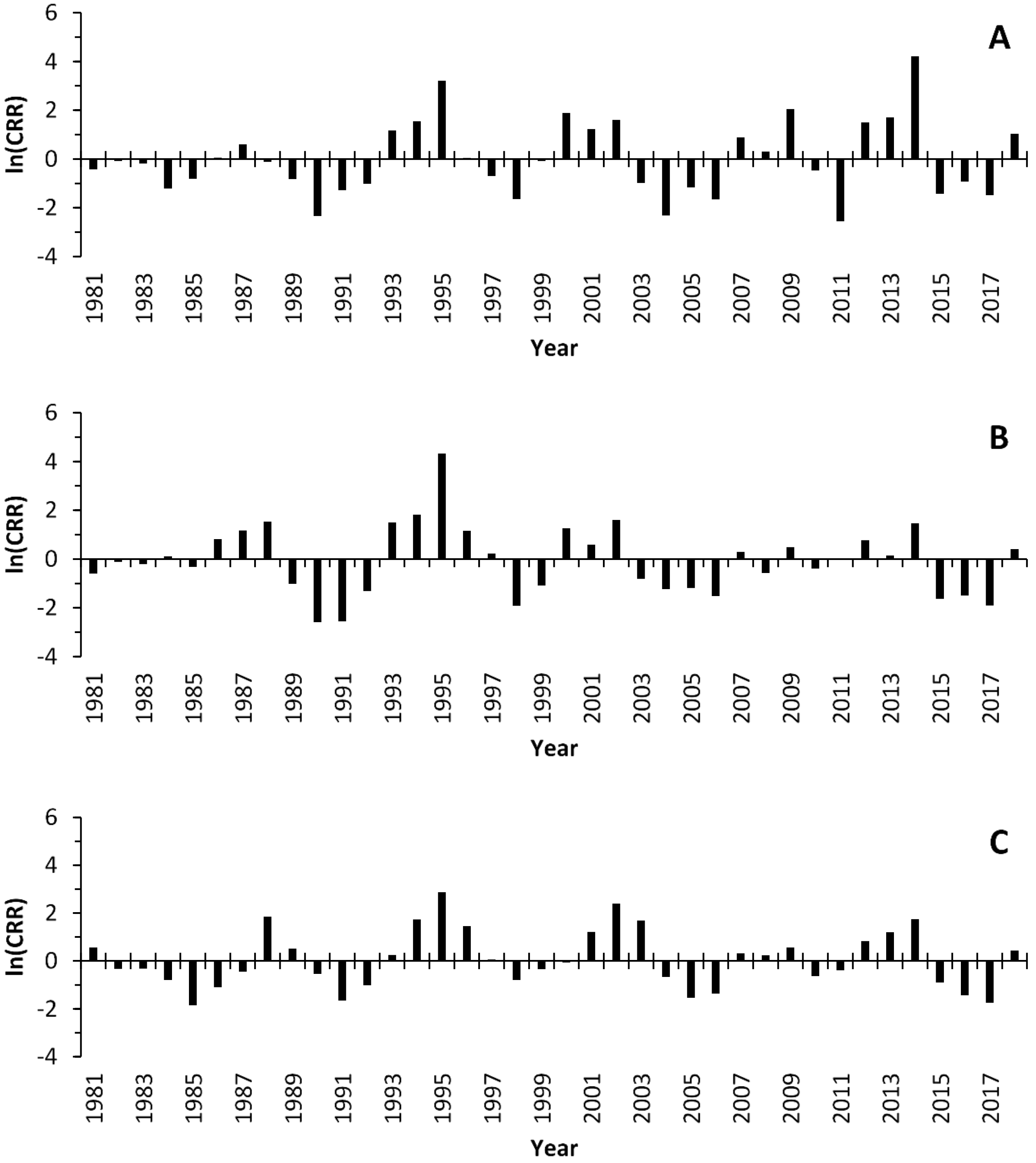

Figure 4.7. Natural log-transformed Cohort Replacement Rates (*ln*CRR) for three fall population components of UKTR Chinook Salmon ESU: A) Shasta River, B) Bogus Creek, and C) Mainstem Klamath River (excluding Iron Gate Hatchery Returns). Data are adult natural area spawning fish only. Gaps are due to years with missing data.

4.4.4 UKTR Chinook Salmon ESU (Spring and Fall Population Components) Growth Rate

In their ESA status review of UKTR Chinook Salmon, Williams et al. (2013) presented growth rate calculations for nine UKTR spring and fall Chinook Salmon population components (Table 4.10). Growth rate was calculated using the methods of Dennis et al. (1991) and Good et al. (2005). Growth rate (lambda; λ), can be used to evaluate population growth or decline: λ < 1 indicates decline, λ > 1 indicates growth over the time series analyzed. These calculations assume that the populations being analyzed are sufficiently isolated from one another such that their persistence trajectories are distinct. It is likely, however, that the population components of the UKTR Chinook Salmon ESU have considerable overlap; therefore, these results should be interpreted carefully.

Growth rate, commonly called the “finite rate of population increase” (or “per individual growth rate”), was calculated over a single time step (usually, but not necessarily, one year) as:

$$\lambda = N_{t+1}/N_t$$

Where *N* is the census number each year *t*. Growth rate is the change in number of individuals observed in successive years (or other time periods).

To reduce the effects of process and measurement errors in the annual survey data, Williams et al. (2013), following Good et al. (2005), used four-year running sums of annual adult escapement estimates, rather than the sequence of annual estimates in one-year time steps (McClure et al. 2003, Good et al. 2005). The four-year running sums were calculated as:

$$R_t = \sum_{i=0}^{3} N_{t-1}$$

Estimates of mean (μ) and variance (δ^2) of successive four-year running sums are calculated as:

$$\hat{\mu} = mean\left\{ln\left(\frac{R_{t-1}}{R_t}\right)\right\}$$

$$\hat{\delta}^2 = var\left\{ln\left(\frac{R_{t-1}}{R_t}\right)\right\}$$

These estimators correspond to the average slope (μ) and variance (δ^2) of the series of four-year running sums of annual abundance for each population component over the time series available.

Using the above estimators of mean (μ) and variance (δ^2), growth rate can be calculated as:

$$\lambda = \exp\left(\hat{\mu} + \frac{\delta^2}{2}\right)$$

Adding one-half the variance to the average of successive ratios of *R* results in an unbiased estimate of λ (Dennis et al. 1991). Note that if the variance is large in relation to the mean, even negative values of μ can give positive estimates of λ.

Confidence intervals were calculated as in Dennis et al. (1991; Equation 68):

$$exp\left[\tilde{r} \pm z_{\alpha/2}\sqrt{\tilde{\delta}^2\left(\frac{1}{t_q}+\frac{\tilde{\delta}^2}{2(q-1)}\right)}\right]$$

Except for the Upper Trinity River spring Chinook Salmon, all other long-term growth rate estimates are above one, indicating average growth over the long-term time frame (Table 4.10); however, confidence intervals for all estimates bracket one indicating uncertainty about the direction of population component trajectory. The declining growth rate estimate for the Upper Trinity spring Chinook Salmon was complicated by missing data that forced the analysis to include a shorter time frame than desired. The long- and recent- time frames for this population component are similar — they may not really represent different time frames.

The short-term growth rates for four of the six fall Chinook Salmon population components (Upper Klamath, Scott, Salmon, and Upper Trinity rivers) were above one, indicating average growth. Trend for Bogus Creek should be interpreted with caution because it is heavily influenced by returns of fall ecotype fish to Iron Gate Hatchery. Two of the six (Bogus Creek and Shasta River) were below one (declining). Growth rate estimates for the Upper Trinity and South Fork Trinity River spring Chinook Salmon was below one, but for Salmon River was above one; however, as for the long-term estimates, all confidence intervals bracketed one, indicating high uncertainty about the actual growth rate for the both spring and fall Chinook Salmon population components.

As reported in Williams et al. (2013), the federal Biological Review Team (BRT) concluded, using this and other analyses (not shown), that there had been little change in growth rate since the review of Myers et al. (1998); however, the BRT noted that current abundance levels of some populations are low, both absolutely and in historical context. The BRT noted specifically that Salmon River and South Fork Trinity River spring Chinook Salmon had low recent abundance below 1,000 fish annually.

Table 4.10. Growth rate (λ) calculations for nine UKTR spring and fall Chinook Salmon population components. From: Williams et al. 2013, Table 2 (Original data from Pacific Fishery Management Council 2011, Appendix B; CDFG 2011a, CDFG 2011b); methods described by Good et al. 2005.

Population Component	Eco-type	Long-term Years	Long-term λ	Long-term Upper 95% CI	Long-term Lower 95% CI	Short-term Years	Short-term λ	Short-term Upper 95% CI	Short-term Lower 95% CI
Bogus Creek	Fall	1978-2010	1.140	0.935	1.391	1998-2010	0.902	0.755	1.077
Up. Klamath R.	Fall	1978-2010	1.101	0.956	1.267	1998-2010	1.102	0.866	1.402
Shasta River	Fall	1957-2010	1.052	0.949	1.166	1998-2010	0.990	0.781	1.255
Scott River	Fall	1978-2010	1.037	0.939	1.146	1998-2010	1.009	0.821	1.240
Salmon River	Fall	1978-2010	1.049	0.953	1.155	1998-2010	1.076	0.877	1.320
Upper Trinity R.	Fall	1978-2010	1.114	0.942	1.316	1998-2010	1.010	0.905	1.128
Salmon River	Spring	1990-2010	1.133	0.962	1.335	1998-2010	1.154	0.959	1.388
Upper Trinity R.	Spring	1996-2010	0.962	0.799	1.157	1998-2010	0.976	0.776	1.229
SF Trinity River	Spring	1985-2011	1.056	0.899	1.239	1999-2007	0.880	0.728	1.065

4.5.6 Diversity

UKTR spring Chinook Salmon are a diversity element (an ecotype) within a larger interbreeding group containing more numerous UKTR fall Chinook Salmon. Together these comprise the UKTR Chinook Salmon ESU. Current assessments indicate that the allele associated with spring migration timing is not common in some portions of the range, but may be more common in others, and that these alleles can be found in the heterozygous condition (Thompson et al. 2019; Anderson et al. 2019; Anderson and Garza 2019). Although UKTR spring Chinook Salmon groups are fragmented and at low numbers, the spring ecotype could regenerate from existing genetic variation if conditions favoring the spring life-history type were to improve and expand in the basin.

4.6 Conclusions: Status and Trend

4.6.1 Status

Although historical numbers are not specific or well documented, it is qualitatively clear that the UKTR Chinook Salmon ESU was much larger in the historical past than today. The UKTR spring Chinook Salmon ecotype, although once perhaps the largest portion of total Chinook Salmon returns to the Klamath-Trinity system, have declined substantially, and disproportionately, in comparison to both historical ESU abundance and UKTR fall Chinook Salmon abundance.

Adult escapement estimates for UKTR spring Chinook Salmon from 1979 to the present are highly variable ranging from low to moderately high (1000s) depending on the population component. Recent UKTR spring Chinook Salmon geometric mean abundance (5-years) is lower than longer time period estimates for all population components. Recent geometric mean abundance for UKTR spring Chinook Salmon in the Salmon River (100s), and especially in the South Fork Trinity River (10s) are low. In contrast, the UKTR spring Chinook Salmon ecotype in the Upper Trinity River persist at much higher average numbers (1,000s). Although there is evidence that the spring ecotype is in decline in at least two of the three extant locations, the larger combined UKTR Chinook Salmon ESU is not.

UKTR fall Chinook Salmon geometric mean abundance has declined, but recent estimates for all spawning aggregations are still in the 1,000s of fish. When UKTR spring and fall Chinook Salmon population components are combined into genetic groups, comprising both ecotypes over a larger number of surveyed sites, their geometric means are in the 10,000s. Similarly, the UKTR Chinook Salmon ESU overall geometric mean abundance is in the 10,000s, which indicates that the threat of extinction for the UKTR Chinook Salmon ESU is low.

4.6.2 Trend

When evaluated as their own “species” or “populations” adult return trends of UKTR spring Chinook Salmon show weak evidence of decline for all three population components over the long-term monitoring period; however, confidence intervals for these average trend estimates range from below to above one. Therefore, the Department cannot conclude that long-term declines over the monitoring period have occurred with certainty.

Recent trends for returning adult Salmon River and South Fork Trinity River UKTR spring Chinook Salmon population components are stronger, showing statistically supported declines over the last four generations (12 years). On average, naturally spawning populations comprised of spawning spring Chinook Salmon adults seem to have declined in these two groups, with stronger evidence for declines in the two smallest (least abundant) population components in recent years.

However, UKTR spring Chinook Salmon are only one of two (along with fall) ecotypes of the combined UKTR Chinook Salmon ESU that are connected by gene flow. Looking at trends in the connected UKTR fall Chinook Salmon component shows a combination of positive and negative trends over the time periods analyzed. Only the long-term average growth of the Mainstem Klamath UKTR fall Chinook Salmon group is supported statistically.

When available UKTR spring and fall Chinook Salmon escapement estimates are aggregated into genetically defined groups, only weak evidence for declines is observed in the Trinity River Group with a lack of statistical support for the trend in either group.

Overall, the Department finds that most trends in UKTR Chinook Salmon, regardless of how they are grouped, show uncertainly weak decline in some places over some time periods. There is better evidence in the monitoring data of recent (12-year) declines in UKTR spring Chinook Salmon in the Salmon River and the South Fork Trinity River.

4.6.3 Productivity

Overall, UKTR spring Chinook Salmon population components show about as many “above replacement” as “below replacement” years since about 1979. The Upper Trinity River and South Fork Trinity River spring Chinook Salmon show recent below replacement years, but with an upturn in 2019. However, UKTR spring Chinook Salmon in the Salmon River have been at less than replacement for an extended period (2013 – 2019) without a recent upturn.

UKTR fall Chinook Salmon population components show similar cycling of CRRs to that of UKTR spring Chinook Salmon. Both fall and spring ecotypes show similar recent low productivity, suggesting that they are responding to similar environmental conditions. The 2014 – 2017 drought likely had a strong effect on productivity of the UKTR Chinook Salmon ESU as a whole.

4.6.4 Growth Rate

Williams et al. (2013) concluded that there had been little change in growth rate for the UKTR Chinook Salmon ESU since the original evaluation in Myers et al. (1998). There are no data prior to those used by Myers et al. (1998) to compare recent with historical growth rates.

4.6.5 Diversity

Taken as a whole, the UKTR Chinook Salmon ESU retains fish that express both spring and fall returning phenotypes and heterozygotes carrying both spring and fall alleles are present in the system; however, UKTR spring Chinook Salmon in the Salmon River and South Fork Trinity River remain at low numbers. Genetic evidence suggests that the spring ecotype could be regenerated by existing fish heterozygous for the “spring allele” if and when conditions favoring the spring ecotype become available. However, because of the small numbers of early returning UKTR spring Chinook salmon currently in the Klamath River, stock transfers would likely be necessary to accelerate colonization there. If conditions that allow successful expression of the early returning life-history strategy do not improve or get worse, then loss of the early migration allele through genetic drift is very likely.

5. Habitat Essential for Continued Existence of the Species

5.1 Adult Migration

Potential factors that influence migratory behavior of UKTR spring Chinook Salmon in the Klamath basin include discharge, water temperature, dissolved oxygen levels, and access to holding areas and tributary streams. Historically, returning adult migrants entered the Klamath River estuary in March (Snyder 1931), but contemporary river entry now appears to commence in April. Peak arrival in the estuary, based on angler catch data obtained during creel surveys, is mid-June to mid-July ending in mid-August (Troxel 2018). Unlike smaller coastal streams, the Klamath River rarely loses connection to the ocean due to sand bar formation, but if it does, it rarely remains a barrier to adult migration for more than a day or two. In addition, river mouth closures typically occur in late summer/early fall when instream flow is at its lowest and after UKTR spring Chinook Salmon have entered the system. Therefore, adult entry into the Klamath River by UKTR spring Chinook Salmon does not appear to be constrained by river mouth blockages.

Returning spawning fish migrate to holding or spawning areas primarily during daylight, though it is not clear why (Neave 1943). Strange (2010) studied the migration behavior of fall Chinook Salmon in the Klamath River and found that elevated temperatures strongly affect migratory behavior. As temperatures reach stressful levels fish begin to seek thermal refugia to reduce metabolic demand, quickly migrating between thermal refugia as they move upstream (Strange 2012). A daily mean temperature of 23° C, a mean weekly temperature of 22° C, or a maximum weekly temperature of 23° C are thought to be complete migration barriers to adult Chinook Salmon in the Klamath River (Strange 2012). River temperatures during the Klamath River entry and migration of UKTR spring Chinook Salmon (April – August) ranges between 8-26° C[10].

Stream temperature is the most critical habitat element associated with UKTR Chinook Salmon migration in the Klamath River. Ambient stream temperatures dictate migration rates, holding times, susceptibility to disease, gonadal maturation, metabolic processes, and pre-spawn mortality rates (Strange 2010, Marine and Cech 2004, CDFW 2004).

5.2 Summer Holding

Chinook Salmon complete their migration when they find suitable holding areas, generally in upstream reaches of mainstem rivers or tributaries (Moyle 2002). Holding primarily occurs in deep water with cover provided by boulders, rock outcroppings, aquatic vegetation, or surface turbulence (NRC 2004). Large pools may assume greater importance for summer holding in low

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[10] Department of Water Resources, California Data Exchange Center, http://cdec.water.ca.gov/dynamicapp/QueryF?s=knk

water years due to potential for pool stratification and suitable temperatures, whereas in higher water years temperatures may be suitable across a range of pool volumes and habitat types (Barnhart and Hillemeier 1994). When temperatures are suitable across habitat types (e.g., pools, runs and glides), holding adult spring Chinook Salmon tend to be more widely and evenly distributed. When temperatures are more heterogenous with areas of stressful or higher temperatures (e.g., in low water years), holding spring Chinook Salmon are more associated with pools (Barnhart and Hillemeier 1994, Torgersen et al. 1999). High pre-spawn mortality has been observed among holding adult UKTR spring Chinook Salmon when daily average temperatures were greater than 21° C for more than a few days (Williams 2006).

5.3 Spawning

For UKTR spring and fall Chinook salmon migration and spawn timing information see Section *2.2 Life History and Unique Characteristics*.

Habitat necessary for successful UKTR spring Chinook Salmon spawning is characterized by appropriate thermal regimes and dissolved oxygen levels (pre-spawn holding and spawning), proper stream depth and velocity and adequate physical properties of the stream bed (gravel and fine sediment composition) for redd construction. In addition, prime spawning habitat will have proximity to escape cover, deep pools, large woody debris, or stream-morphological characteristics such as undercut banks.

Suitable depths and velocities for redd construction seem to vary widely (Healy 1991), but most spawning seems to occur at depths of 25 – 100 cm and velocities of 30 – 80 cm/sec (Moyle 2002). Extensive observations in the Trinity River documented that most Chinook Salmon spawning is at depths ranging from 15 – 76 cm and velocities ranging from 23 – 76 cm/sec (Hampton 1997). Spawning gravel size varies considerably as Chinook Salmon have been observed spawning in gravel with a median diameter ranging from 11.2 – 78.0 mm (Kondolf and Wolman 1993). However, Platts et al. (1979) report that Chinook Salmon preferentially select gravel ranging from 7 – 20 mm. Redds are constructed by females, and the size of spawning gravel scales with the female body size (Kondolf and Wolman 1993).

Intergravel water flow, which provides dissolved oxygen for developing eggs and removes metabolic wastes, is a key feature guiding redd site selection. Intergravel flow may play a more important role in spawning site selection than water depth or velocity (Healey 1991).

Microhabitat selection for redd construction based on physical parameters of water depth, water velocity, substrate size, temperature, and other factors are clearly important, but physical access to suitable habitat in the historic distribution of UKTR spring Chinook Salmon (e.g., upstream of dams) is also critically important. Historically, UKTR spring Chinook Salmon spawning was likely more temporally and spatially segregated from UKTR fall Chinook Salmon, which played an important role in maintaining the distinctness between the two runs by reducing interbreeding (Williams 2006).

5.4 Egg and Larval Development

Developing eggs require dissolved oxygen levels of at least 5.0 mg/l, with survival increasing with as oxygen levels approach saturation; however, dissolved oxygen alone does not appear to be sufficient to maintain high survival of eggs. Good intergravel flow is also required. Even at saturated oxygen levels, reduced intergravel flows have been found to reduce survival (Shumway et al. 1964, as cited in Reiser and Bjornn 1979). While decreased flow is generally associated with decreased dissolved oxygen, when oxygen levels are sufficient to support growth and survival of eggs, flow is also needed, presumably, to remove metabolic waste (Reiser and Bjornn 1979). In order to maintain sufficient intergravel flow, spawning gravels should have less than 25% fines (≤ 6.4 mm), though less is better (Reiser & Bjornn 1979).

5.5 Fry Emergence

After hatching, UKTR spring Chinook Salmon alevins may live in gravel for 4 – 6 weeks prior to emergence, usually until the yolk sac is fully absorbed (Moyle et al. 2015). The alevin life-stage is generally less susceptible than eggs to suboptimal temperature and dissolved oxygen levels, as they can move short distances within the gravel to escape poor conditions. However, temperatures higher than optimal water temperatures or other suboptimal inter-gravel conditions can result in premature emergence in salmonids (e.g., Beer and Steel 2018, Fuhrman et al. 2017). When fish emerge prior to complete yolk sac absorption, the yolk sac can interfere with locomotion and orientation (Thomas et al. 1969), making them more susceptible to predation (Fresh and Schroder, 1987).

Emerging fry require similar habitat characteristics as the egg and larval life-stages, including gravel substrate with adequate intergravel flow and water quality and suitable water temperature and dissolved oxygen. Even if embryos hatch and develop, fry survival may be poor if they are prevented from emergence by excessive amounts of sand and silt in the gravel (Reiser and Bjornn 1979). Although field evidence looking specifically at fry emergence is sparse, laboratory studies have found that Chinook Salmon emergence is impacted when sediments less than 6.4 mm in diameter made up more than 20% of the substrate (Bjornn 1969 and McCuddin 1977, as cited in Reiser and Bjornn 1979). Emergent fry experience higher survival if high quality rearing habitat is nearby and accessible (Chamberlain et al. 2012).

5.6 Juvenile Rearing and Emigration

Juvenile UKTR spring and fall Chinook Salmon are difficult to visually differentiate in the Klamath and Trinity rivers due to variability in spawn timing and developmental rates, so most field studies simply characterize juvenile Chinook Salmon habitat broadly rather than distinguishing requirements of the spring and fall ecotypes. Younger, smaller fish rely more heavily on shallow water closer to stream margins and cover. As they grow older and larger, they take advantage of deeper water and higher velocities while having less reliance on cover (Allen 2000). Goodman et al. (2010) performed an extensive observational study of fry and presmolt habitat preferences in the Trinity River finding that optimal habitat for fry included depths less than 0.61 m, velocities less than 0.15 m/sec, and distances to cover of less than 0.61 m. Those values increased to less than 1.0-meter depth, velocities less than 0.24 m/sec, and distances to cover of less than 0.61 m. Cover included aquatic or overhanging vegetation, woody debris, or boulders. Juvenile Chinook Salmon in other locations also use floodplain and off-channel waters when available to capitalize on increased prey densities and warmer temperatures compared to that in the mainstem (Sommer et al. 2001). In mainstem rivers like the Klamath, where temperatures during the juvenile rearing season reach stressful or lethal levels and diseases are present, thermal refugia ≥2° C cooler than mainstem temperatures can decrease vulnerability to disease (Chiaramonte et al. 2016).

5.7 Estuaries

The Klamath River estuary is relatively small in relation to the large size of the watershed. Tidal influence only extends to about rkm 6.5 (RM 4.0) during typical high tides with saltwater intrusion ranging from only 4 to 6 km (2.5 – 3.7 miles) upstream of the mouth. Because of its small size, the Klamath River estuary does not provide the level of ecological services to the extent that larger estuaries do (e.g., presence of large tidal marshes and flats); however, the Klamath estuary does provide nursery and rearing habitat for many fish species and is a critical staging area for anadromous fish migrating between ocean and freshwater. These areas are essential transition zones for out-migrating juvenile and returning adult Chinook Salmon and other salmonids.

Annual precipitation in the Klamath basin is approximately 200 cm, resulting in large seasonal freshwater inputs to the Klamath estuary and coastal waters. Freshwater inputs, habitat-forming processes, habitat quality (e.g., hydrologic processes, water quality, and nutrient transport) and sediment transport are strongly affected by reduced and managed flows due to dams in the region and other anthropogenic activities. Estuaries and bays are especially vulnerable to coastal development, pollution, invasive species, and coastal fishing.

Also because of its size, and the presence of a sandbar at the river’s mouth, the Klamath estuary is “river-dominated” having limited coastal exchange. Foraging habitat for anadromous juveniles is found in associated wetlands, sloughs, and off-channel waters. For example, juvenile salmonids use beaver ponds in small tributaries as seasonal rearing habitat. Coastal environments are also affected by Klamath River flows through the estuary to the nearshore ocean. Physical processes mediated by river flows affect creation of reefs and outcroppings, rocky intertidal zones, and sandy beaches along the nearby coast (Thorsteinson et al. 2011).

6. Factors Affecting the Ability to Survive and Reproduce

Numerous published evaluations and summaries (e.g., NRC 2008; Stanford et al. 2011; USDI et al. 2012; NMFS 2013) describe stressors impacting UKTR Chinook Salmon habitat and biological modifications in the Klamath basin. Stressors include habitat loss due to dam construction and operation, reduced flows, presence of drainage infrastructure and canals, loss of wetlands, and increases in nutrient and sediment inputs. This section describes the major factors that affect the ability of UKTR spring and fall Chinook Salmon to survive and reproduce. The section also considers potential future impacts of climate change and ocean conditions.

6.1 Dams and Diversions

Dam construction and operation, along with land and water use practices, have fragmented populations and degraded habitat quality in the Klamath-Trinity basin (NRC 2004). Prior to European colonization salmonid runs were likely much larger (650,000-1,000,000 fish annually) than today (Gresh et al. 2000, citing Radke, personal communication).

Dams have been a common feature of the Klamath basin since initial federal funding for hydrologic projects in the early 20th Century. The National Reclamation Act was passed in 1902 and the Klamath Irrigation Project began construction in 1906. The latest project, Keno Dam (OR), was completed in 1967. Approximately 57% of the irrigated agricultural land in the upper basin is provided by the Klamath Irrigation Project (owned by the United States Bureau of Reclamation [USBR]), including 240,000 acres of croplands in southern Oregon and northern California (Chaffin et al. 2015). Dam building and power generation in the region was overseen by the California Oregon Power Company (COPCO). The Copco 1 Dam was the first to be constructed in 1909 and the most recent project in California was construction of Iron Gate Dam in 1962 (Chaffin et al. 2015). COPCO merged with Pacific Power and Light (abbreviated PacifiCorp) in 1961. PacifiCorp's Klamath Hydroelectric Project (FERC No. 2082) currently consists of seven hydroelectric developments: Eastside, 3.2 MW; Westside, 0.6 MW; J.C. Boyle, 98 MW; Copco 1, 20 MW; Copco 2, 27 MW; Fall Creek 6, 2.2 MW; Iron Gate, 18 MW; and one non-generating dam (Keno). The project generates approximately 716 gigawatt-hours of electricity annually, enough to supply 70,000 households. PacifiCorp operates the Link River Dam (owned by USBR) in coordination with the company's other hydroelectric projects. The Link River Dam located upstream of PacifiCorp's projects (Table 6.1, Figure 6.1) controls storage within and releases from Upper Klamath Lake, the largest freshwater lake in Oregon. Keno Dam, located 35.4 km (22 miles) downstream of the Link River Dam, does not produce electricity but regulates the water level in Keno Reservoir/Lake Ewauna as required by the operating license for the project issued by the Federal Energy Regulatory Commission (ESSA 2017).

Table 6.1. Major dams in the Klamath basin including their distance from the Pacific Ocean (river kilometer). J.C. Boyle, Copco 1 and 2, and Iron Gate Dams make up the Klamath Hydroelectric Project (KHP) and currently anticipated to be removed in 2022. Iron Gate Dam is the current upstream limit of anadromy. Rkm = river kilometer; RM = river mile. From: ODFW and the Klamath Tribes 2019, with modification.

Dam	River	State	Rkm	RM	Year completed
Link River Dam	Link River (head of Klamath R.)	Oregon	414.4	257.5	1927
Keno Dam	Klamath River	Oregon	380.5	236.4	1966
J.C. Boyle Dam	Klamath River	Oregon	366.9	228.0	1958
Copco 1 Dam	Klamath River	California	324.9	201.9	1918
Copco 2 Dam	Klamath River	California	324.4	201.6	1925
Iron Gate Dam	Klamath River	California	312	193.9	1962
Dwinnell Dam	Shasta River	California	65	40.4	1928
Trinity Dam	Trinity River	California	193	119.9	1962

6.2 Habitat Condition

Habitat conditions for all salmonids in the Klamath basin have been affected by numerous anthropogenic factors including urbanization, agriculture, forestry, mining, dams/hydropower, and fishing (Thorsteinson et al. 2011). Habitat fragmentation has negatively affected UKTR spring Chinook Salmon migration, foraging for food, predator avoidance, and productivity. Poor instream habitat condition has also affected their ability complete their life cycle through increased mortality at all life stages (Thorsteinson et al. 2011). Dams in the basin have blocked access to upstream spawning and rearing habitat, creating reservoirs that altered (degraded) temperature and flow conditions, and affected nutrient and sediment transport processes. Land disturbance/conversion and water withdrawals have altered natural flows, increased local thermal loading, reduced natural wood inputs, and increased nutrient inputs and contaminant concentrations (Thorsteinson et al. 2011).

The condition of the remaining accessible habitat in the Klamath basin is a primary factor leading to reduced representation and distribution of the UKTR spring Chinook Salmon ecotype. The primary causes of UKTR Chinook Salmon habitat degradation in the Klamath basin are dams, water management, legacy gold mining, and forestry. Barriers, particularly during low flows, restrict movement and migration. Historical mining operations, logging, and land use conversion cause geomorphic changes, including slope and bank instability and erosion of fine sediment input to the channel, which decreases the quality of spawning habitat and reduces complexity of the low flow channel (NMFS 2014).

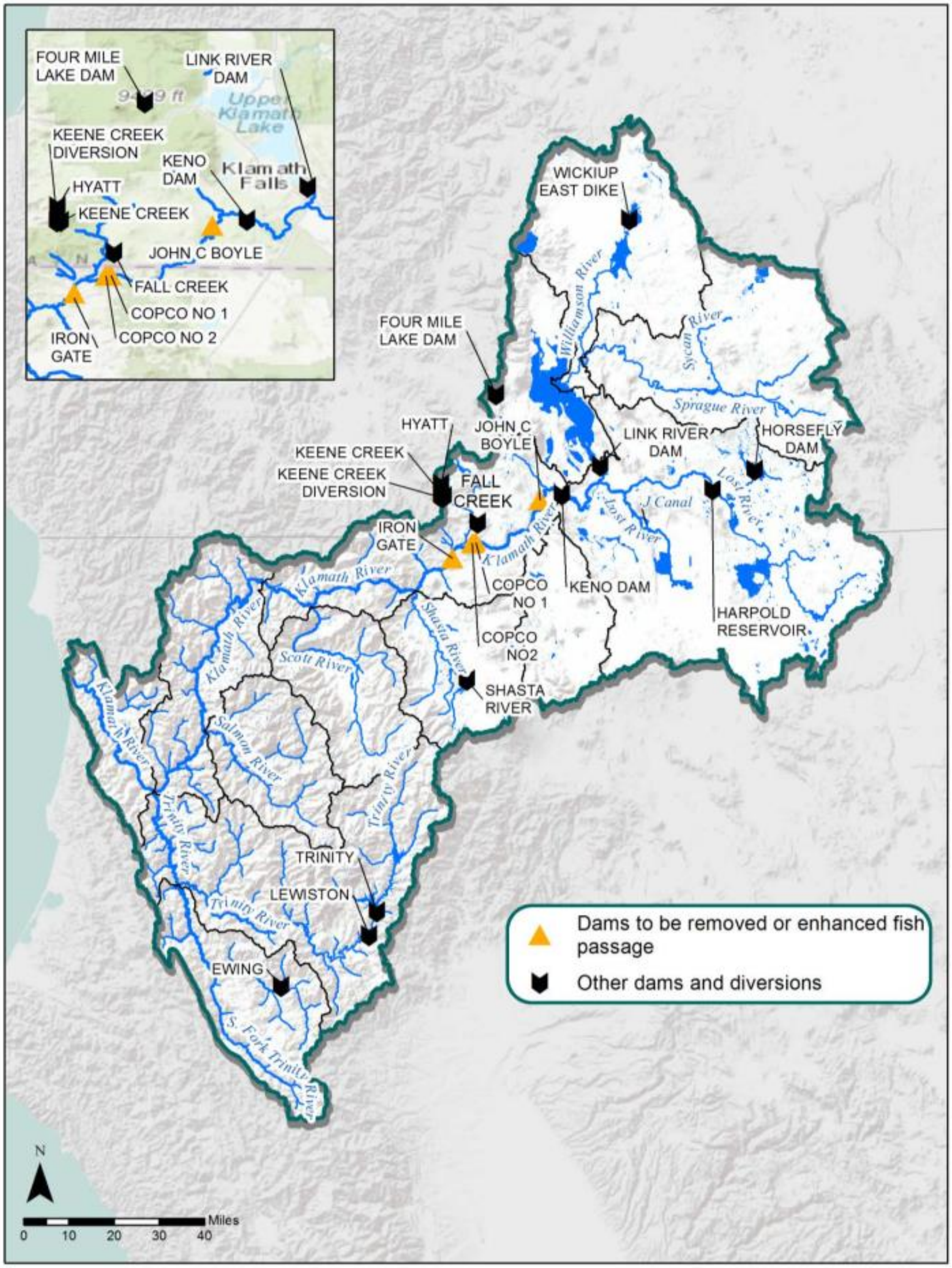


Figure 6.1. Dams and diversions in the Klamath-Trinity basin in California and Oregon. Inset shows four dams currently scheduled for removal. From: ESSA 2017.

Historically, the Klamath River was fed by shallow lakes and marshes that provided cold water inputs during drier periods. Over 80% of these wetlands have been drained, which has led to decreased flows and higher water temperatures (NRC 2004). In the Trinity and Salmon Rivers, land use changes and groundwater pumping have led to a disconnection of surface and groundwater that also results in higher temperatures and lower summer flows (NRWQCB 2005). These decreased flows and high summer water temperatures are exacerbated by loss of riparian cover and reduced structure in the low flow channel (NRWQCB 2005), which further reduces habitat quality for both UKTR spring and fall Chinook Salmon (NRC 2004). The Salmon River is identified as impaired for temperature in accordance with Section 303(d) of the federal Clean Water Act (NRWQCB 2005). Elevated summer water temperatures in the Salmon River limits carrying capacity by restricting adult holding and juvenile rearing of UKTR spring Chinook Salmon to a few thermal refugia (NMFS 2014).

Other Clean Water Act Section 303(d) listings for impaired waters in the basin include:

- Lower Klamath River downstream of the Trinity River for nutrients, organic enrichment/low dissolved oxygen, and temperature;
- Klamath River between the Scott and Trinity rivers for hepatotoxic microcystins from cyanobacteria, nutrients, organic enrichment/low dissolved oxygen, sediment, and temperature;
- South Fork Trinity River for mercury, sedimentation/siltation; and
- East Fork Trinity River for mercury, sedimentation/siltation.

The geology of the Trinity Alps is such that hillslopes are highly susceptible to erosion. Throughout the basin, logging and logging roads have decreased stability of the already steep and unstable slopes. Fine sediment enters the rivers and clogs spaces between gravel, reducing hyporheic flow and salmon egg survival (NRC 2004). Furthermore, deforestation reduces the recharge of aquifers due to faster runoff and less groundwater recharge, which in turn reduces groundwater input to streams during dry months.

In the Salmon River, legacy gold mining has had a profound effect on habitat condition. Hydraulic mining led to considerable channel aggradation, widening and shallowing alluvial reaches, coarsening the bed, reducing habitat complexity, filling of pools, decreasing connection with groundwater, and reducing floodplain connectivity (Stillwater Sciences 2018; NMFS 2014). Placer mining added an estimated 20.3 million cubic yards of sediment to river and eroded over 1,800 acres of riparian and floodplain (Hawthorne 2017; de la Fuente and Haessig 1993, as cited in Stillwater Sciences 2018). These impacts disconnect and/or significantly reduce the amount and quality of spawning, adult holding, and rearing habitat in the Salmon River (NMFS 2014).

The Upper Trinity River was dammed and diverted as part of the Central Valley Project, and the currently accessible portion is highly modified by legacy gold mining and a severely modified flow regime. Beginning in 1964, the USBR began diverting up to 90% of Upper Trinity River flow into the Sacramento River basin, which was followed by a severe decline in UKTR spring Chinook Salmon and other anadromous fishes (NRC 2004). Nearly two decades of fishery studies in the Upper Trinity River informed a flow study (USFWS 1999) that became the basis of a process resulting in formation of the Trinity River Restoration Program (TRRP; USDI 2000). The TRRP's restoration strategy includes managing instream flows, mechanical channel rehabilitation, gravel augmentation, watershed restoration to reduce fine sediment input, improving infrastructure to accommodate floodplain inundation, and an adaptive management program. Channel rehabilitation projects associated with the TRRP—including mechanical alteration of the channel, riparian planting, wood placement, and gravel augmentation—were evaluated in 2014 (Buffington et al. 2014). The review concluded that restoration actions have increased salmon habitat, although not as much as the TRRP targeted, and that management actions had a modest positive effect.

In the South Fork Trinity River, unsustainable grazing and farming has led to loss of riparian habitat, erosion, and geomorphic changes (NRC 2004). These impacts increase stream temperature, decrease habitat quality through loss of complexity and input of large wood, and increase erosion and sedimentation.

Poor water quality and quantity are stressors on both UKTR spring and fall Chinook Salmon in the Klamath River. High temperature and low dissolved oxygen create critically stressful conditions, especially for UKTR spring Chinook Salmon adults and juveniles in the summer months (June through September). Salmon productivity in the Salmon River is limited by high water temperatures that reduce adult holding and summer rearing habitat in the mainstem Salmon River, while increased fine sediment input within the watershed reduces spawning and rearing habitat quality in some locations (Elder et al. 2002).

6.3 Climate Change Projections and Potential Fish Habitat Impacts

The Earth's climate is warming, and the primary causes are greenhouse gas emissions and deforestation (IPCC 2007; USGCRP 2009; USGCRP 2017). A warming climate is likely to result in poorer future environmental conditions for California's salmonids in general, and for UKTR spring Chinook Salmon specifically.

Since 1900 global average temperature has increased 0.7° C (NRC 2006) due to carbon dioxide emissions. Ice core data indicates that atmospheric carbon dioxide is currently 30% greater than its peak in the last 800,000 years. Over the last 150 years, carbon dioxide levels have increased 37.5% (Figure 6.2).

These greenhouse gas increases have resulted in changes in seasonal precipitation, decreased snowpack, earlier snowmelt, and increased storm severity (USGCRP 2009; USGCRP 2017), 0.1° C increase in seas surface temperature since 1961 and increased ocean acidification (USGCRP 2009), 203 mm increase in sea level after approximately 2000 years of stability (USGCRP 2009), and approximately a 20% decrease in the amount of arctic sea ice since the 1950s (Curran et al. 2003).

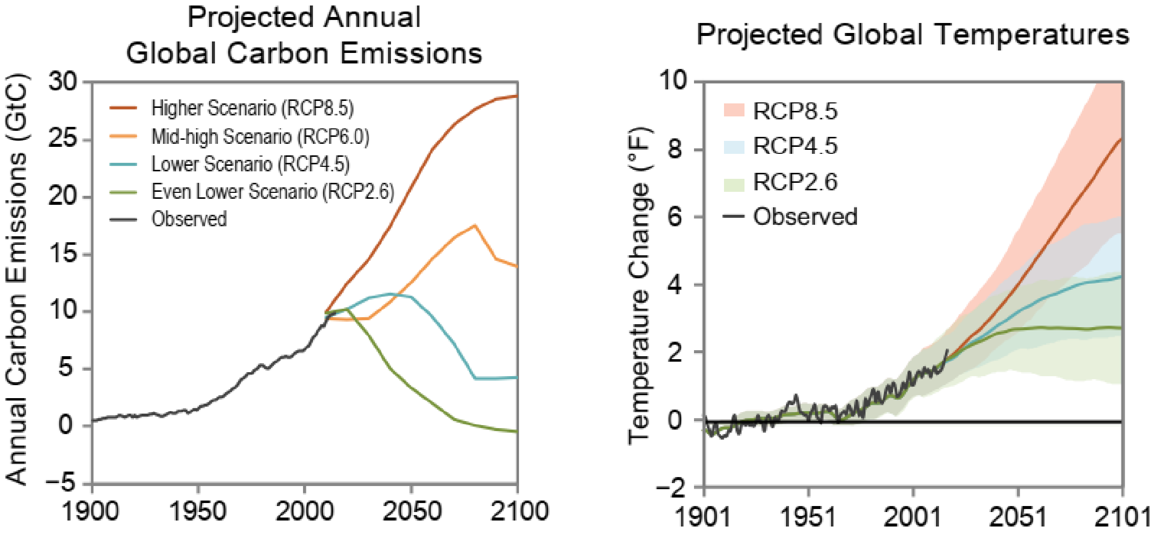


Figure 6.2. Annual historical and range of plausible future carbon emissions (gigatons of carbon per year) and historical and future temperature change for a range of future scenarios relative to the 1901 – 1960 average. Lines show central estimates and shaded areas show 2-standard deviation range as simulated by the CMIP5 global climate models. Projected range of global mean temperature change by 2081 – 2100 for lower to higher carbon reduction scenarios is 1.1 – 4.3 °F (green), 2.4 – 5.9 °F (blue), 3.0 – 6.8 °F (not shown), and 5.0 – 10.2 °F (orange). From: USGCRP 2017.

By the end of this century, atmospheric carbon dioxide concentrations are projected to be two to three times greater than in the last 800,000 years (Figure 6.3). If current conditions remain unchanged, studies project that global climate will change drastically. Projections include an increase of 1.1 – 6.4° C in average global surface temperature (USGCRP 2009), sea level rise of 1 – 3 m (IPCC 2007; USGCRP 2009; USGCRP 2017), and greater extremes in storm events and wildfire (Krawchuck et al. 2009).

UKTR Chinook Salmon are likely to experience worsening environmental conditions in the future as a result of climate change. The UKTR spring Chinook Salmon ecotype may be disproportionately affected because of their life history that includes an early adult return and extended holding period in freshwater. Issak et al. (2018) compiled multidecadal climate data and calculated trends at 391 riverine sites on Northwestern rivers. Recent 20- and 40-year periods saw warming trends in summer and early fall of 0.18 – 0.35° C per decade between 1996 – 2015 and 0.14 – 0.27° C per decade between 1976 – 2015. These changes paralleled air temperature trends and were mediated by local trends in discharge. The authors found that future warming of 1 – 3° C would increase Sockeye Salmon *(O. nerka*) exposure by 5 – 16% and reduce thermally suitable riverine trout habitat by 8-13% causing an upstream shift in distribution. The study found that most salmon and trout rivers in the Northwestern United States will continue to provide habitat for salmonids into the foreseeable future; however, they also concluded that some river reaches will inevitably become too warm to support salmonid habitat.

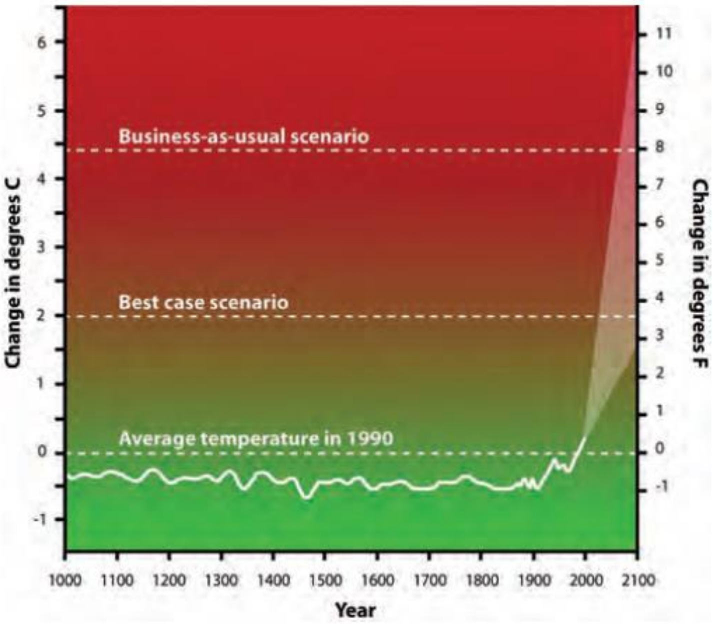


Figure 6.3. Global mean temperature for the last 1,000 years and projected temperatures to 2100. Constant lines show average temperature in 1990, best case scenario if greenhouse gas emissions are drastically cut, and projected temperature if greenhouse gas emissions increase at current rate. From: Barr et al. 2010, adapted from IPCC 2007.

In a modeling study of water temperature specific to the lower mainstem Klamath River, Bartholow (2005) found evidence of increases of 0.5° C per decade (95% CI 0.42 – 0.60° C) since the early 1960s. The period of stressful high temperatures has also increased by one month with average amount of cool water in summer declining approximately 8.2 km (5.1 miles) per decade. Water temperature changes were not associated with water availability but were associated with increases in air temperature and possibly ocean conditions (i.e., Pacific Decadal Oscillation cycle). The author concluded that the warming trends predicted for the Klamath River could negatively impact salmonid recovery in the basin.

Cline et al. (2019) examined the potential effects of climate change and competition on Sockeye Salmon life history. The authors found that warming climate decreased the time spent in the freshwater phase due to enhanced growth at higher temperature. This in turn led to younger age at the time of ocean entry. Early ocean entry in turn caused a potential for increased ocean competition with both hatchery-origin and natural-origin fish that delayed maturity in the ocean. Consequently, fish spent an additional year in the ocean phase prior to return. Smaller size at age also affected the vulnerability to fisheries. Climate warming increasingly favors a shift to a single dominant age class, but simplification of age class complexity degrades resiliency by reducing variation in life-history expression. Although Cline et al.'s (2019) study specifically referenced potential climate change impacts to Sockeye Salmon in Alaska, similar warming scenarios could also be relevant to Chinook Salmon in California, including potential for future declines of the UKTR spring Chinook Salmon life-history type.

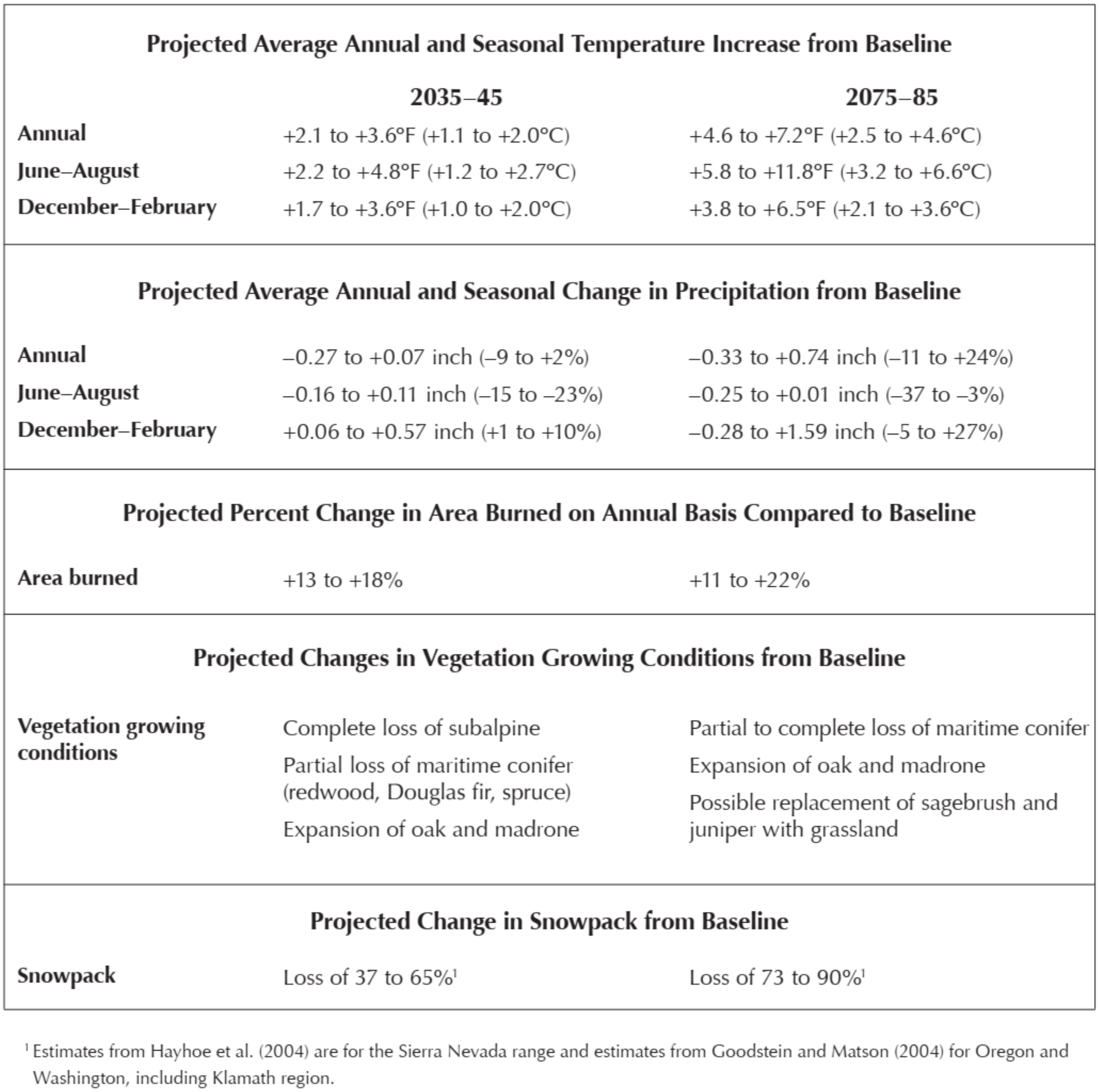
The Klamath-Trinity basin is very large resulting in highly variable current climatic conditions from the lower to upper basin (Table 6.2). Temperatures are generally lower in the upper and lower basins and higher in the mid basin region. Precipitation in the upper basin is often snow, whereas in the lower and mid basins precipitation is mostly rain.

Table 6.2. Average temperature and precipitation in the upper, mid, and lower Klamath basin.

Basin	Location	Average annual high/low temp (°F)	January Average high/low temp (°F)	July Average high/Low Temp (°F)	Precipitation (inches)
Upper	Klamath Falls	61/35	38/21	86/51	13.5
Mid	Orleans	71/44	51/35	93/54	51
Lower	Klamath	61/45	54/38	66/52	80

Climate change projections for the Klamath basin are for generally warmer and drier conditions in comparison to those in the past. Barr et al. (2010; Figure 6.4) present results of climate models and a vegetation model for the Klamath basin. Models project annual average temperature increase by about 1.1 – 2.0° C by mid-century, and 2.5 – 4.6° C by late century. Summer warming was projected to be greater than warming in other seasons. Average annual precipitation projections were for a potential range of 11% decrease to 24% increase in rainfall; however, they found that all models showed future summers likely to be 3 – 37% drier than in the past. Vegetation modeling predicted a shift in the upper basin to conditions favoring grasslands in places where climate now supports sagebrush/juniper vegetation type. Conditions in the lower basin favored oak/madrone communities where maritime coniferous forests (coast redwood, Douglas fir, Sitka spruce) now predominate.

Current water quality in the basin is poor in many places and is likely to decline further in the future due to projected increases in water temperature. The Klamath basin is likely to experience warmer water, fluctuating dissolved oxygen levels, and earlier, longer, and more intense algal blooms. More frequent disease outbreaks are also projected due to lower stream flow and increased temperature. Temperature refugia will increase in importance for aquatic species.



	2035–45	2075–85
Projected Average Annual and Seasonal Temperature Increase from Baseline		
Annual	+2.1 to +3.6°F (+1.1 to +2.0°C)	+4.6 to +7.2°F (+2.5 to +4.6°C)
June–August	+2.2 to +4.8°F (+1.2 to +2.7°C)	+5.8 to +11.8°F (+3.2 to +6.6°C)
December–February	+1.7 to +3.6°F (+1.0 to +2.0°C)	+3.8 to +6.5°F (+2.1 to +3.6°C)
Projected Average Annual and Seasonal Change in Precipitation from Baseline		
Annual	–0.27 to +0.07 inch (–9 to +2%)	–0.33 to +0.74 inch (–11 to +24%)
June–August	–0.16 to +0.11 inch (–15 to –23%)	–0.25 to +0.01 inch (–37 to –3%)
December–February	+0.06 to +0.57 inch (+1 to +10%)	–0.28 to +1.59 inch (–5 to +27%)
Projected Percent Change in Area Burned on Annual Basis Compared to Baseline		
Area burned	+13 to +18%	+11 to +22%
Projected Changes in Vegetation Growing Conditions from Baseline		
Vegetation growing conditions	Complete loss of subalpine Partial loss of maritime conifer (redwood, Douglas fir, spruce) Expansion of oak and madrone	Partial to complete loss of maritime conifer Expansion of oak and madrone Possible replacement of sagebrush and juniper with grassland
Projected Change in Snowpack from Baseline		
Snowpack	Loss of 37 to 65%[1]	Loss of 73 to 90%[1]

[1] Estimates from Hayhoe et al. (2004) are for the Sierra Nevada range and estimates from Goodstein and Matson (2004) for Oregon and Washington, including Klamath region.

Figure 6.4. Climate change projections of climate and vegetation models applied to the Klamath basin due to climate change. From: Barr et al. 2010.

More fine sediment is projected due to more frequent and more intense storms and more precipitation occurring as rain. Erosion will likely increase, leading to negative impacts on spawning salmon. Other fish species in the basin (e.g., steelhead, trout, suckers, lamprey) will be likewise affected. Sediments will contain large nutrient loads that will likely further exacerbate algal blooms.

Stream flow is projected to increase in winter and decrease in other seasons because more precipitation will likely be in the form of rain. Frequency of flooding may also increase. Shifting flow patterns and flooding could affect migration timing of adult and juvenile anadromous fish, possibly altering selective regimes that support existing diversity patterns. Because more precipitation is projected to fall as rain in future, snowpack will be reduced, and the melt season will be shorter. This could affect flow patterns and reduce off channel nursery areas. Decreased flows in spring, summer, and fall are likely. Streams that are currently at low flows will likely become intermittent or might cease flowing altogether.

Groundwater flows originating from springs are likely to decline and small springs could dry entirely. Cold water refugia are currently important to anadromous fish in portions of the basin (e.g., Shasta River and other places; Belchik 1997) and are likely to increase in importance with projected changes in climate (Barr et al. 2010).

6.4 Disease

Disease strongly affects anadromous salmonids and other fish in the Klamath River. Principal diseases include ceratomyxosis, columnaris disease, and *Ichthyophthirius multifilis* (“ich”). In some years, these diseases have severely impacted Klamath fish populations causing large die-offs of both juveniles and adults. Seasonal flow management adjustments (e.g., at Trinity River and Link River dams) are used to reduce downstream disease outbreaks when they occur. Disease outbreaks in both the upper and lower basin are triggered and worsened by poor water quality that simultaneously favors disease vectors and stresses fish, making them more susceptible to infection (ESSA 2017).

Several pathogens have been found to contribute to mortality in wild Chinook Salmon in the Klamath River basin. In 2002, a large die-off of adults in the lower Klamath River was attributed to infection with a combination of ich and *Flavobacterium columnare* (columnaris) (USFWS 2003, CDFG 2003). High infection rates of juveniles, with *Ceratonova shasta* and *Parvicapsula minibicornis*, have also been linked to disease and reduced numbers of UKTR Chinook Salmon (Stocking and Bartholomew 2004; Nichols and Foott 2005).

Since 2005, growth of toxic algae behind Copco 1 and Iron Gate dams resulted in posted health warnings against water contact (especially health concerns associated with microcystin toxin) in the two reservoirs and the Lower Klamath River (USDI et al. 2012).

Other pathogens endemic to the Klamath basin that can cause disease in salmonids include bacterial infections caused by *Renibacterium salmoninarum* (the causative agent of bacterial kidney disease, or BKD), *Flavobacterium psychrophilum* (the causative agent of bacterial cold water disease, or CWD), *Aeromonas hydrophila*, and *Yersinia ruckeri* (the causative agent of enteric redmouth disease, or ERM); *Saprolegnia* sp. (external water mold); *Nanophyetus salmincola* (Foott et al. 1997); and various external protozoan (single-celled) and monogenean (flatworm) parasites. Infectious hematopoietic necrosis virus (IHNV) has not been isolated from fish at Trinity River Hatchery since 1999 or from fish at Iron Gate Hatchery since 1997; however, the Department's virology records indicate that it remains common in Sacramento Valley Chinook Salmon runs.

Environmental factors that may contribute to disease include elevated water temperature, low dissolved oxygen, low water flow, elevated pH, and elevated nutrient levels. Toxic cyanobacteria blooms have also been detected in the Klamath River watershed (Fetcho 2006).

Climate change is predicted to negatively influence several of these environmental factors, increasing risk of disease and pathogen effects on the UKTR Chinook Salmon ESU. Therefore, this factor may have a greater effect on survival and reproduction of the ESU in the future.

6.5 Climatic Variation in the Ocean

The California Current Ecosystem (CCE) runs from the southernmost part of California up through the coast of Washington and serves as home to California's salmonid species during the oceanic portion of their life cycle. The CCE can be divided into three sections: the area north of Cape Mendocino is considered the "Northern CCE", the area between Cape Mendocino and Point Conception is the "Central CCE", and south of Point Conception is the "Southern CCE." Fluctuations in key physical and biological variables such as temperature, currents, and forage species can help serve as indicators to the overall health and stability of the CCE as it relates to Pacific salmon. Several basin-scale indices are used to track fluctuations and changes in the CCE to help inform management through illustration of current and historical trends in the marine environment.

Sea surface temperature plays an important role in marine survival of salmon. Cool water periods are generally associated with increased oceanic circulation and upwelling of nutrient-dense water that feeds lower trophic levels. Nutrients move through the food chain supporting populations of plankton and forage species, which in turn provide a food-rich environment for salmon. Conversely, warm water periods are generally associated with reduced upwelling and more nutrient deficient waters that are less supportive of healthy prey species populations.

The Pacific Decadal Oscillation (PDO) is a climate index that reflects long-term fluctuations in sea surface temperatures in the Northeast Pacific. The PDO is classified into either warm water phases or cool water phases that can persist for decades. In the PDO Index from 1925-2018 (Figure 6.5), the shifts between warm and cool water cycles lasted for more than two decades prior to 1998 (Peterson et al. 2018). Long-term cycles have become less stable in recent years, resulting in more frequent fluctuations without long periods of stability in between. Since 1998, warm and cool water cycles have lasted no more than 6 years before switching to an alternate state (Peterson et al. 2018). The shift from decadal cycles to more frequent fluctuations in ocean conditions translates to a less stable environment for salmon during their marine phase. Shorter periods of a healthy marine environment with an abundant food supply may threaten the development of robust salmon populations.

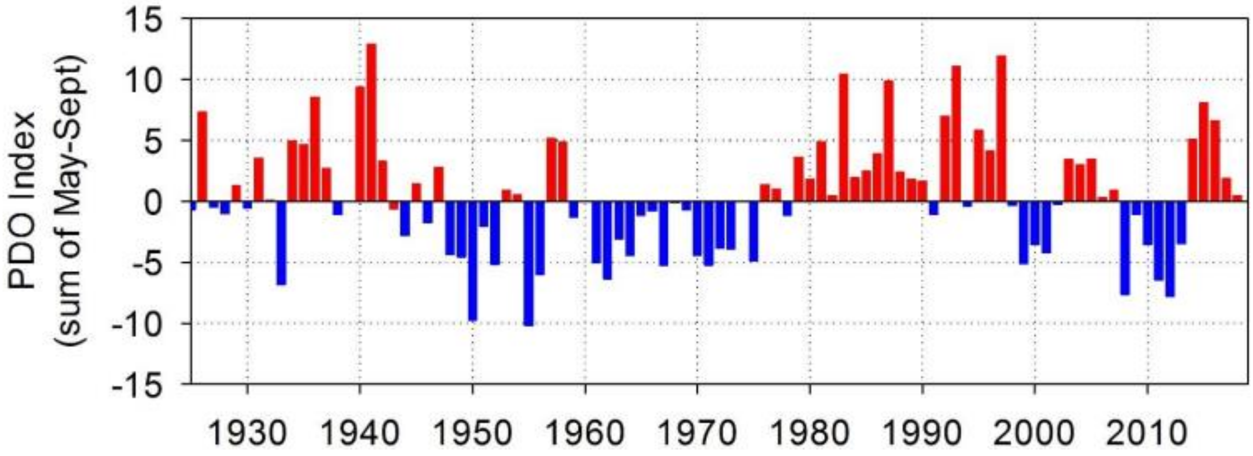


Figure 6.5. Time series of shifts in sign of the Pacific Decadal Oscillation (PDO), 1925 – 2018. Values are summed over the months of May through September. Red bars indicate positive (warm) years; blue bars indicate negative (cool) years. From: Peterson et al. 2018.

The El Niño Southern Oscillation (ENSO) is a periodic fluctuation in wind and sea surface temperatures moving across the equatorial Pacific Ocean that also influences water temperatures in the CCE. The Oceanic Niño Index (ONI) tracks changes in sea surface temperature and reflects fluctuations between El Niño phases characterized by warm water conditions, and La Niña phases characterized by cool water conditions. Strong El Niño events result in the transport of warm equatorial waters northward into the CCE and are generally associated with weaker upwelling, lower primary productivity, and change in community composition of salmon forage species. La Niña conditions are associated with cool water periods and higher productivity. Strong El Niño events were observed in 1972, 1983-84, 1997-98, and more recently in 2015-2016 (Figure 6.6).

The North Pacific Gyre Oscillation (NPGO; Figure 6.7) index tracks changes in sea surface height in the North Pacific. Fluctuations in the NPGO index are indicative of the type of source waters entering the CCE. Positive NPGOs are associated with increased flow from subarctic source waters which bring in higher surface salinities, nutrients, and chlorophyll-*a* to the CCE resulting in stronger circulation, coastal upwelling, and higher productivity at the lower trophic levels. Negative NPGOs are associated with weaker oceanic circulation and lower productivity. Over the last five years, the NPGO has declined to near historic lows indicating a recent trend of weak circulation, low influx of nutrient-rich water, and low primary productivity (NMFS 2019).

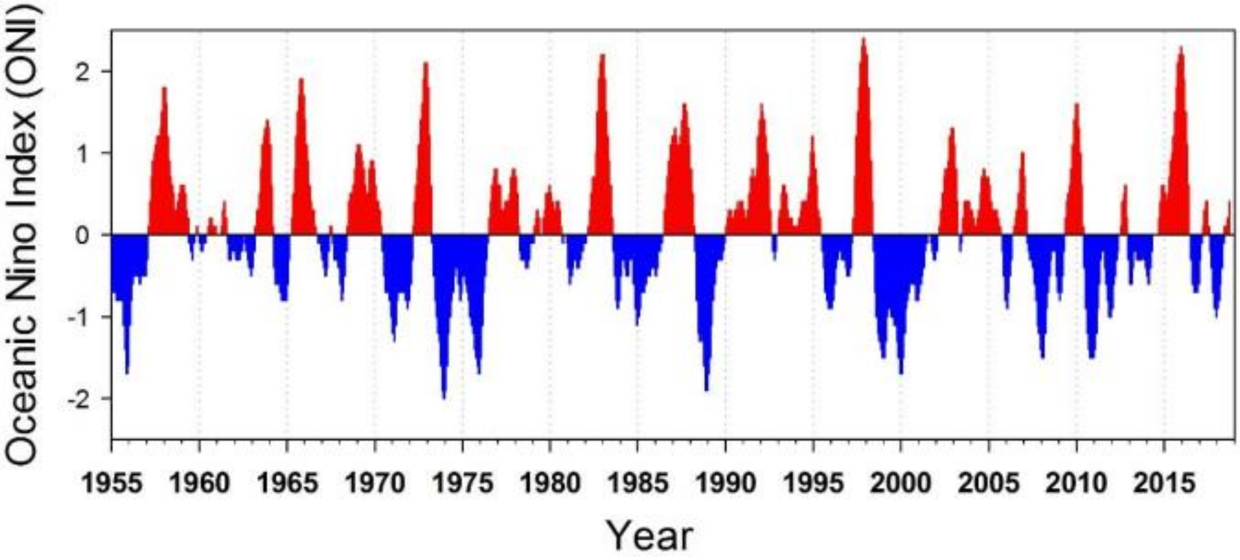


Figure 6.6. Values of the ONI, 1955 – 2018. Red bars indicate warm conditions in the equatorial Pacific, blue bars indicate cool conditions in equatorial waters. From: Peterson et al. 2018.

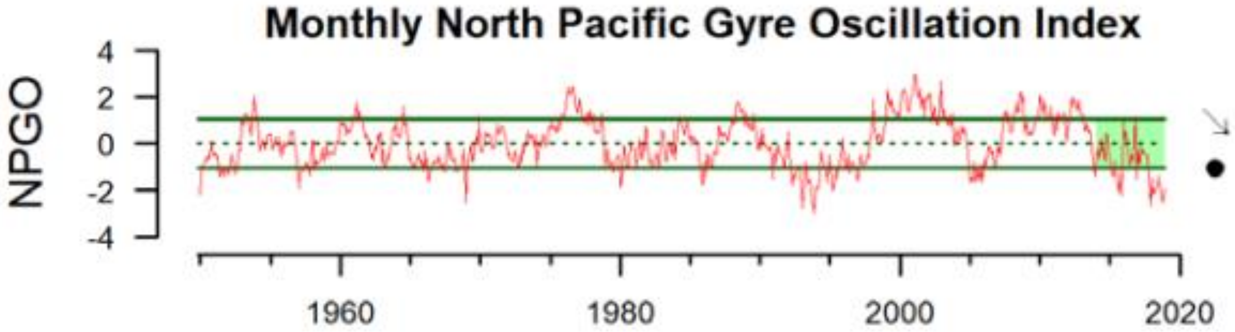


Figure 6.7. Monthly values of the North Pacific Gyre Oscillation (NPGO) from 1950 – 2018. Indicator data relative to the mean (dashed line) and ±1 standard deviation (solid lines) of the full time series. Arrow at the right indicates if the trend over the evaluation period (shaded green) was positive, negative, or neutral. From: NMFS 2019.

Regional climatic conditions also play an important role in ocean temperatures and nutrient content in the waters off the California coast (Figure 6.8). Wind systems near the land-sea interface drive coastal upwelling, where wind stress displaces surface waters and deep, nutrient rich waters move up to replace it. Jacox et al. (2018) developed new indices to estimate coastal upwelling. The Cumulative Upwelling Transport Index (CUTI) estimates the vertical transport of water into and out of the surface layers, and the Biologically Effective Upwelling Transport Index (BEUTI) estimates the nutrient content. Together, these indices track the total volume of water moving into and out of the surface layer as well as the quality of that water in terms of nutrient content, which greatly influences productivity. The timing of peak upwelling varies by latitude. Within the Central CCE around Point Arena (CA), the strongest upwelling and peak nitrate flux generally occurs in May and June. During winter, this same area undergoes downwelling and low nitrate flux due to reversing winds. In 2018, BEUTI and CUTI values were generally average through most of the year with particularly strong periods up upwelling and nitrate flux during the spring.

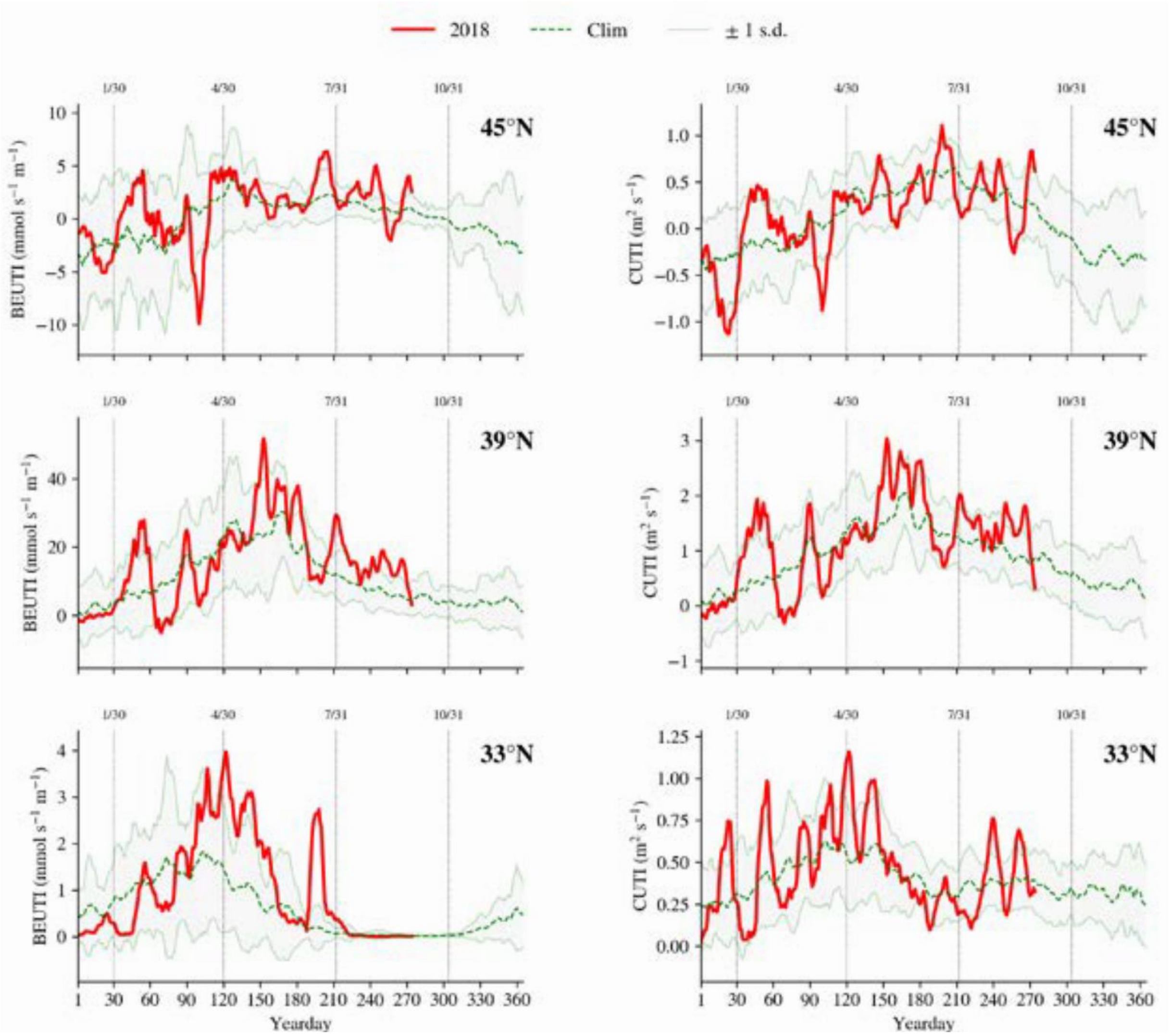


Figure 6.8. Daily 2018 values of Biologically Effective Upwelling Transport Index (BEUTI; left) and Coastal Upwelling Transport Index (CUTI; right) from Jan. 1 – Sept. 1, relative to the 1988 – 2018 climatology average (green dashed line) ±1 standard deviation (shaded area), at latitudes 33° (Southern CA near Point Conception), 39° (Point Arena, CA), and 45°N (Newport, OR). Daily data are smoothed with a 10-day running mean. Vertical lines mark the end of January, April, July, and October. From: Harvey et al. 2019.

Composition and abundance of zooplankton communities are also good indicators of productivity at the lower levels of the trophic system (Figure 6.9). Copepods are an important food source for young Chinook Salmon when they first enter the ocean as well as for many other forage species of fish, such as herring, sardines, and anchovies. However, the nutritional quality of different copepod communities varies greatly depending on their source waters. The CCE is host to several different types of copepod communities: northern copepods – cold-water species rich in fatty acids, and southern copepods – warm-water species with lower fat content and nutritional quality. Southern copepods are more abundant in the CCE during warm-water conditions such as El Niño events and positive PDO regimes, whereas the abundance of lipid-rich northern copepods increases during cool-water conditions such as La Niña years and negative PDO regimes (NMFS 2019). The southern copepod biomass anomaly was particularly strong during the warm water years from 2014 to mid-2017 before moving to a more neutral, and then negative trend by the end of 2018. Within the same time frame, biomass anomalies for northern copepods were negative from 2014 to mid-2017 before moving to more of a neutral value and remaining relatively neutral since. The decline in southern copepods and increase in northern copepods following the recent warm water conditions may signal improved forage conditions for salmon within the northern CCE in recent years (NMFS 2019).

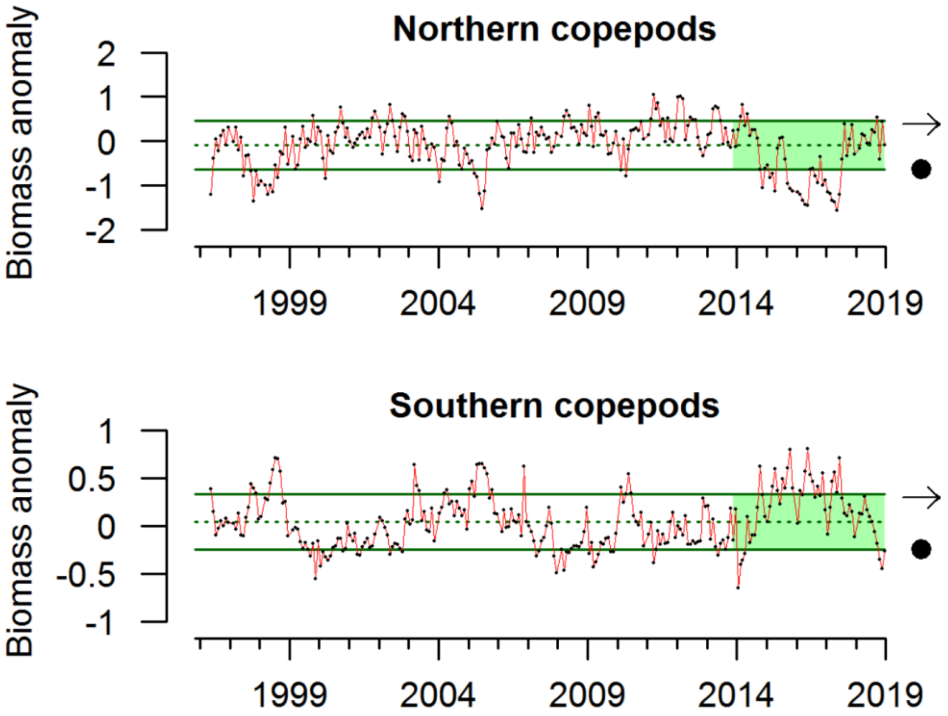


Figure 6.9. Monthly northern and southern copepod biomass anomalies from 1996 – 2018 from transect line off Newport, OR. Indicator data relative to the mean (dashed line) and ±1 standard deviation (solid lines) of the full time series. Arrow at the right indicates if the trend over the evaluation period (shaded green) was positive, negative, or neutral. From: NMFS 2019.

Surveys of the composition and abundance of forage fish species serve as a direct measure of prey abundance for salmon in the CCE. Plots of key forage species in the northern and central CCE over the last 20 years are shown in Figures 6.10 and 6.11. Species are listed on the y-axis and abundance is indicated by color (red signifies abundant and blue signifies rare). Vertical lines indicate a significant shift in regional species composition and horizontal lines indicate clusters of typically co-occurring species. The northern CCE survey of Washington and Oregon saw a dramatic shift in species assemblages beginning in 2014. Between 2006 and 2013, various species of yearling salmon were relatively abundant and market squid were relatively scarce. Beginning in 2014, market squid were consistently abundant and yearling salmon were present only intermittently. In the central CCE, notable changes in species composition started to occur in 2013, as abundance of juvenile sardine, anchovy, market squid, sanddabs, and rockfishes started to climb. Also, worth noting in this cluster analysis is the relative scarcity of adult sardine and herring since 2013, which are common primary prey items for Chinook Salmon in this area; however, adult anchovy, another primary food source for Chinook, were abundant in 2018.

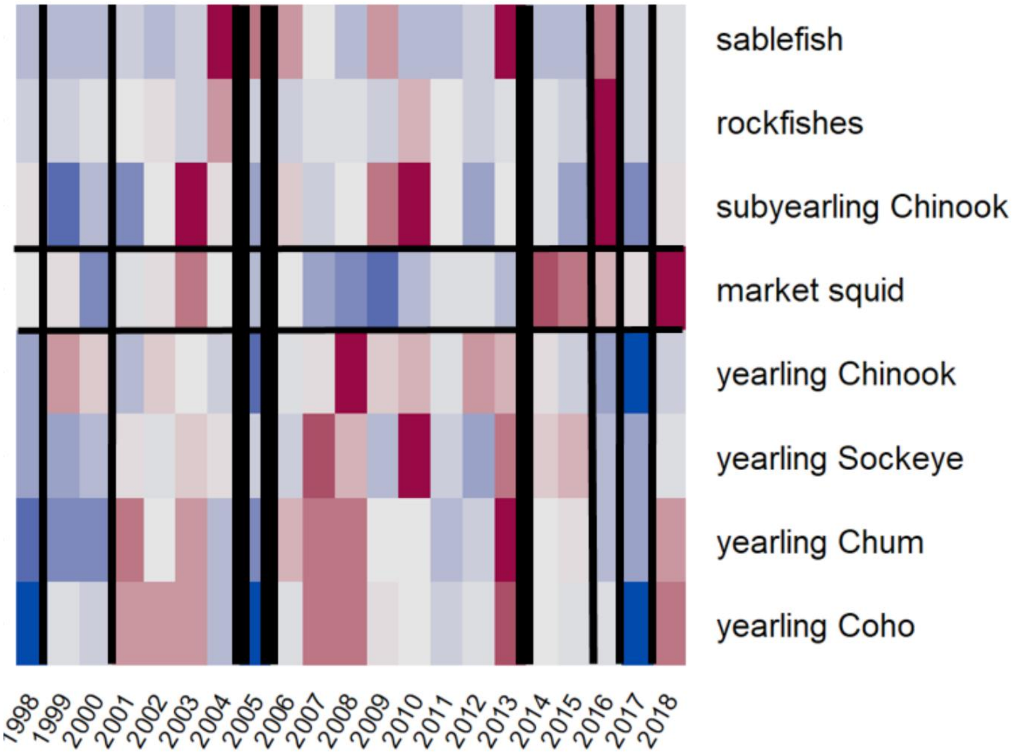


Figure 6.10. Cluster analysis of key forage species in the northern CCE through 2018. Horizontal lines indicate clusters of typically co-occurring species. Vertical lines indicate temporal shifts in community structure. Colors indicate relative abundance (red = abundant, blue = rare). From: NMFS 2019.

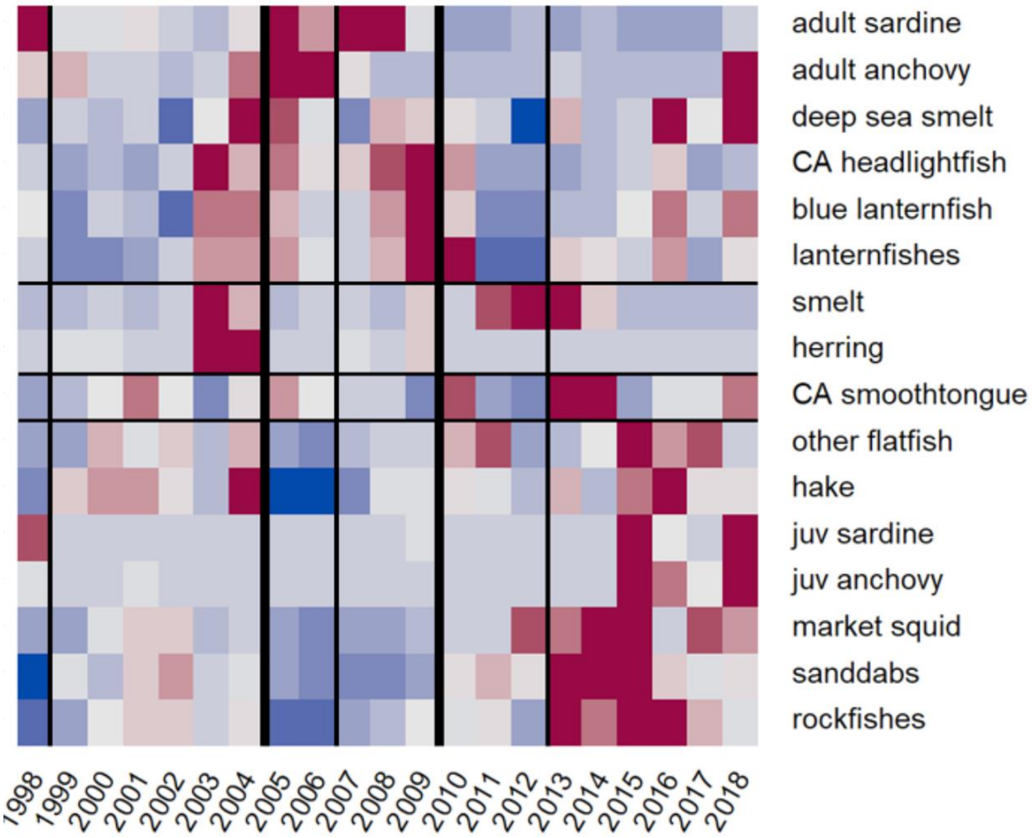


Figure 6.11. Cluster analysis of key forage species in the central CCE through 2018. Horizontal lines indicate clusters of typically co-occurring species. Vertical lines indicate temporal shifts in community structure. Colors indicate relative abundance (red = abundant, blue = rare). From: NMFS 2019.

The marine environment within the CCE has undergone considerable change within the last several years. In addition to the strong El Niño event in 2015-2016 and the positive PDO regime, an unprecedented marine heat wave, popularly known as “The Blob,” appeared off the Pacific coast in 2014-2015. These anomalous and extreme warm water conditions created poor ocean conditions and low prey abundance for salmon, which contributed to historically low adult escapement to both the Klamath and Sacramento river basins in 2017. Fortunately, the above indices indicate a current shift to a more neutral state. However, extremes in ocean conditions are expected to become increasingly common as the effects of climate change are realized.

Ocean acidification, due to increased atmospheric carbon dioxide, is occurring in the world’s oceans, including in the CCE. Sensitivity of salmon to ocean acidification is likely to occur through changes in the food web (Mathis et al. 2015, Busch et al. 2013, Busch et al. 2016), and would be restricted to the marine life-history phase. Abundance of invertebrates such as pteropods, crabs, and krill, which form a large part of the diet of some salmon species, are most likely to be affected by increasing ocean acidity (Wells et al. 2012). Acidification may also act directly on physiological processes affecting olfaction (impairing homing; Munday et al. 2009) and development (Ou et al. 2015). Crozier et al. (2019), using scoring techniques in Morrison et al. (2015) estimated that relative salmon sensitivity is associated with diet. Zooplankton feeders (e.g., Sockeye Salmon, Chum Salmon, Pink Salmon) are more sensitive to ocean acidification than piscivorous species (e.g., Chinook Salmon, Coho Salmon, steelhead). However, populations of Chinook Salmon can also be affected by krill abundance and availability during the period of initial ocean entry (Wells et al. 2012).

6.6 Drought

Drought is a familiar feature of California's climate; however, the most recent 2012-2016 drought was one of the warmest and driest on record, affecting both aquatic and terrestrial environments across the state (Figure 6.12; CDFW 2018a). In response, the Department conducted habitat monitoring for 17 aquatic species/subspecies in 141 watersheds spanning 38 counties throughout the state. Many of the species monitored were state and/or federally listed or California Species of Special Concern. Because of their reliance on cold, clear water for major portions of their life cycle, salmonid fishes were a special focus for monitoring.

Low flow conditions, lasting months during the drought, were expected to be a strong stressor on both juvenile and adult salmonids. Heat stress is known to occur in salmonids at temperatures of 15 – 18° C, with mortality at temperatures above 25°C (Bjornn and Reiser 1991). Low dissolved oxygen levels associated with high temperatures and low flows are lethal for both adults and juveniles below 3.0 mg/L (Matthews and Berg 1997). Due to lack of precipitation, streams that usually flowed all year often went dry in part or entirely during drier portions of the year. Streams experienced earlier drying and compromised habitat conditions (e.g., low dissolved oxygen, low flow, higher temperature). Habitat fragmentation reduced the ability of salmonids and other aquatic species to adapt to poor conditions by moving to better habitat.

Estuaries and lagoons were also impacted by extended drought. Estuaries experienced more pronounced tidal influence due to reduced freshwater inflow. The saltwater bottom layer experienced lower dissolved oxygen levels, likely affecting migrating and rearing juvenile anadromous salmonids. The timing and extent of seasonal river mouth openings deviated from that for non-drought years, affecting timing of anadromous fish migration both into and out of streams.

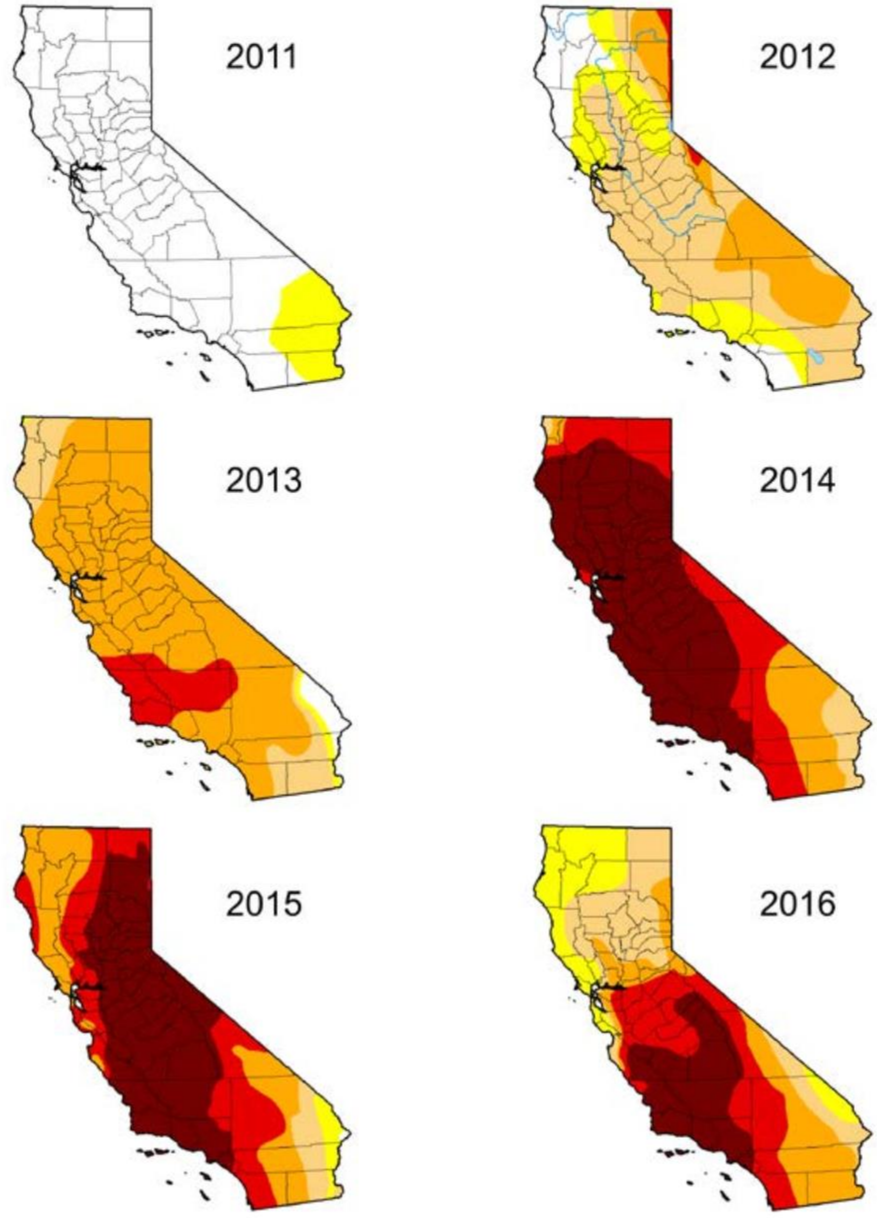


Figure 6.12. The distribution and progression of drought conditions in California from 2011 – 2016, depicting the level of drought at the beginning of each Water Year (October 1). Dark red indicates exceptional drought. From: CDFW 2018a, original map source: U.S. Drought Monitor.

Although the spring ecotype of UKTR Chinook Salmon ESU were not a focal taxon in CDFW (2018a), the overall pattern for coastal anadromous waters was that "higher than normal water temperatures associated with the drought exceeded survival thresholds and probably affected the spawning success and survival of salmon and steelhead in coastal watersheds" (CDFW 2018a). In addition, low flows during the drought period in the Shasta River led to high water temperatures in summer months. Baseflows at the confluence of the Klamath and Shasta rivers were less than 5 cubic feet per second (cfs)—the lowest flows on record. During most of the summer months, maximum daily water temperatures were above 18°C.

Although drought monitoring data specific to effects on the spring ecotype of UKTR Chinook Salmon ESU is scarce, the Department concludes that the recent drought likely had a negative effect on extant populations. Drought conditions may have been a major stressor leading to recent declines observed in both UKTR spring and fall Chinook Salmon.

6.7 Hatcheries

Two anadromous salmonid hatcheries produce UKTR Chinook Salmon in the Klamath-Trinity watershed. Trinity River Hatchery (TRH; on the Trinity River at Lewiston Dam) has had active UKTR spring Chinook Salmon and UKTR fall Chinook Salmon programs since construction of the hatchery in 1964. Iron Gate Hatchery (IGH; on the Klamath River at Iron Gate Dam) was constructed in 1966. IGH historically also produced both UKTR spring and fall Chinook, but currently only produces UKTR fall Chinook Salmon. The Chinook Salmon programs at both hatcheries are considered primarily mitigation to compensate for lost production due to habitat loss above dams.

The following subsections discuss the status, trend, and potential impacts of IGH and TRH hatchery programs on natural and listed fish, the California Hatchery Scientific Review Group performance review, specific program elements at IGH and TRH relevant to status and trend, potential results of dam removal on the Klamath River, and reintroduction plans for UKTR spring Chinook Salmon that potentially involve use of hatchery fish.

6.7.1 Potential Impacts of Hatchery-Origin Fish on Natural-Origin and ESA-Listed Fish

For over a century, hatcheries along the Pacific Coast have produced hundreds of millions of hatchery salmon. Largely these fish have been produced in support of fisheries, although some recent hatchery programs have a conservation focus. Although the number of hatchery fish in the Pacific Ocean is great, natural-origin populations continue to decline.

Anadromous salmonid hatcheries have been a feature of the Klamath basin since the construction of large dams on the Klamath and Trinity rivers blocked access to much of those rivers' anadromous fish spawning and rearing habitat. Both in-river and ocean fisheries are strongly supported by annual releases of large numbers of hatchery Chinook Salmon in this region (see below). Over the entire Pacific Northwest, numerous studies have concluded that hatchery practices, along with large harvests that hatcheries support, have contributed to declines of natural spawning populations of anadromous salmonids (e.g., Waples 1991b, 1999; Lichatowich 1999; Levin et al. 2001; Naish et al. 2007).

Hatcheries have the potential to both increase annual numbers of propagated stocks and negatively impact their long-term prospects for natural area persistence. Impacts can be genetic, ecological, and behavioral (for reviews see CDFG 2002; Naish et al. 2007; Flagg et al. 2000). Competition, predation, straying, stock introgression, masking of declines, reduced fitness, and inbreeding and outbreeding depression have been documented in many studies in many anadromous salmonid species (Naish et al. 2007). Reviews of the potential and realized impacts of hatchery-origin fish on natural stocks can be found in Naish et al. (2007), Flagg et al. (2000), CDFG (2002), among many others. Because of the persistent declines observed in Pacific salmon, including collapse of West Coast salmon fisheries in 2008 (Lindley et al. 2009), the United States Congress authorized recent efforts to improve Pacific salmon hatchery programs in Washington, Oregon, and California (HSRG 2015; CA HSRG 2012).

6.7.2 Introgression of UKTR Spring and Fall Chinook Salmon at Trinity River Hatchery

It is generally assumed that UKTR spring and fall Chinook Salmon were once more reproductively isolated than they are today (see Range and Distribution). The construction of Lewiston Dam on the Trinity River in 1964 resulted in truncation of the total Chinook Salmon spawning habitat, resulting in potential for increased spring and fall interbreeding on the Trinity River. Prior to dam construction on the Trinity River, UKTR spring Chinook Salmon were thought to spawn farther upstream early in the fall, with UKTR fall Chinook Salmon spawning downstream later in the fall (Kinziger et al. 2008b). Artificial propagation of both UKTR Chinook Salmon ecotypes at TRH further increased the chances of unintentional introgression of the spring and fall ecotypes.

Kinziger et al. (2008b) reported on a genetic survey of Chinook Salmon broodstock at TRH during the 1992 return year. They found that the proportion of UKTR spring and fall Chinook Salmon in returning adults shifted over the spawning season, with a higher proportion of UKTR spring Chinook Salmon early in the season and a higher proportion of UKTR fall Chinook Salmon later. Simulation studies showed there is potential for spring-fall hybridization, especially in the middle of the spawning season. The study could not determine whether similar hybridization had been occurring prior to dam construction and hatchery production.

6.7.3 California Hatchery Scientific Review Group Recommendations

Beginning in the year 2000, the United States Congress embarked on a hatchery review process to maintain the social and commercial benefits of anadromous fish hatcheries while protecting natural and listed salmon and steelhead populations. The first review was conducted for Puget Sound and Coastal Washington hatchery programs (2004) and was later expanded to hatcheries in the Columbia River basin (2005). In 2010, Congress authorized and funded a review of most of California’s salmon and steelhead hatchery programs. A group of hatchery experts, the

California Hatchery Scientific Review Group (CA HSRG), was created to conduct the review. Their work over an 18-month period resulted in the CA HSRG review document published in 2012 (CA HSRG 2012).

The goal of the CA HSRG hatchery review was to provide guidance to manage and operate hatchery programs to help recover and conserve listed and naturally spawning salmon and steelhead populations and support sustainable fisheries with little or no deleterious consequence to listed and natural populations. The programs at both IGH and TRH were included in this review.

The CA HSRG developed recommendations for improvement of all hatchery programs at both Trinity River and Iron Gate hatcheries and specific recommendations applied to individual programs with the goal of reducing negative impacts of these hatchery programs. These recommendations can be found in *Appendix A* of this report. Some, but not all, of the recommendations have been implemented.

6.7.4 Iron Gate Hatchery

Iron Gate Hatchery currently produces UKTR fall Chinook Salmon and also conducts a conservation hatchery program for Coho Salmon. It does not currently produce UKTR spring Chinook Salmon, although it did at one time. Prior to 1995-96, IGH also had a robust steelhead program. However, that program produced very few fish in the last decade due to low broodstock returns and was recently terminated.

UKTR fall Chinook Salmon produced at IGH are adipose fin-clipped and coded wire tagged (CWTed) at a constant annual rate of 25% following the Department’s standard. UKTR fall Chinook Salmon production at IGH, along with TRH UKTR spring and fall Chinook Salmon production, form the base stock for in-river and ocean fisheries in the region. The ocean abundance of age-4 IGH UKTR fall Chinook Salmon is also used as a surrogate for management of the ESA threatened California coastal Chinook Salmon ESU (O’Farrell et al. 2015).

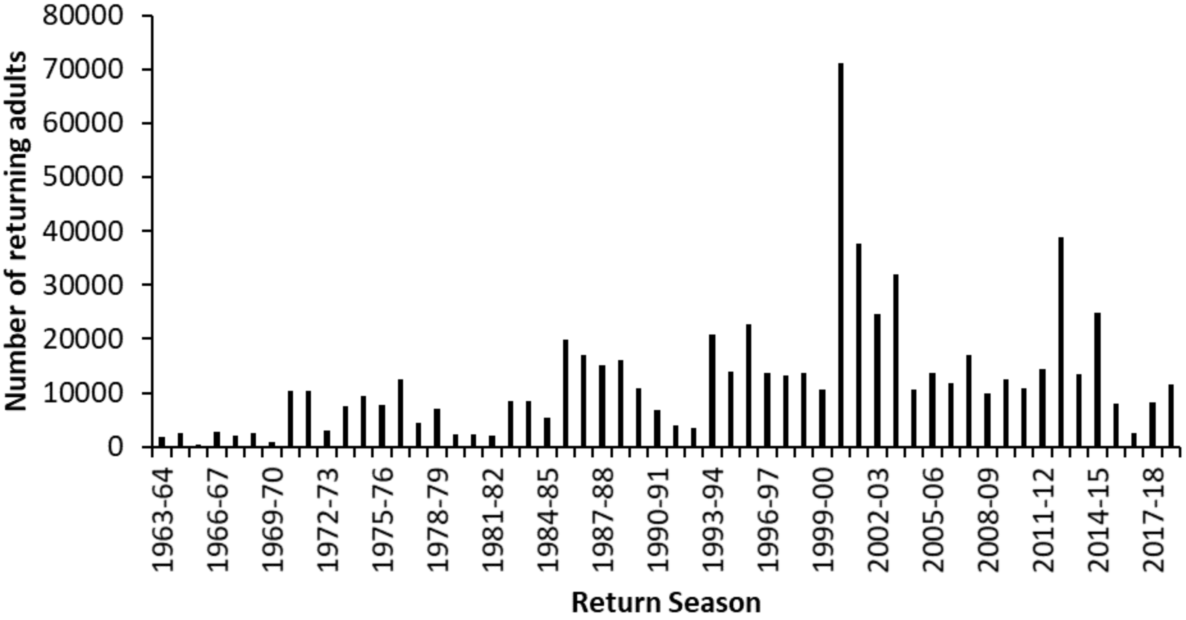


Figure 6.13. Annual total adult UKTR fall Chinook Salmon returns to Iron Gate Hatchery 1963 – 2019.

Annual returns of UKTR fall Chinook Salmon to IGH consistently numbered in the thousands to the tens of thousands throughout the monitoring period (Figure 6.13). The numbers of fish returning since 1985-86 appear to be generally greater than in earlier years. The lowest recent return occurred in the 2016-17 season during which only about 3,000,000 eggs were taken. Current season (2019-20) returns to the hatchery were also relatively low for this program (approximately 4,000 adults; Patrick Brock, CDFW, Personal Communication, November 2019). The most recent notably large season was 2001-02 with more than 71,000 UKTR fall Chinook Salmon returning to the hatchery.

Some UKTR spring Chinook Salmon (generally less than 100 per year; Table 6.3) returned to IGH between 1968 and 1979. Returns were inconsistent and low during this period with decreasing numbers of adults observed over time. The hatchery suspended trapping the following year and between 1979-2001 because spring Chinook Salmon were not observed returning in late- spring or summer. No UKTR spring Chinook Salmon have been recorded trapped at IGH, either early or late in the return season, between 2001 and the present (Table 6.3; Patrick Brock, CDFW, personal communication, November 2019).

Table 6.3. Fall-trapped and spring-trapped UKTR spring Chinook Salmon returning to Iron Gate Hatchery, 1962-2019

Season	Fall-trapping[1] Adult	Fall-trapping Grilse	Spring-trapping Adult	Spring-trapping Grilse
1962-63 through 1967-68	Data Not Available			
1968-69	NA	NA	50	6
1969-70	8	3	51	0
1970-71	2	0	10	0
1971-72	16	0	80	0
1972-73	97	4	49	0
1973-74	18	5	4	0
1974-75	19	8	0	0
1975-76	25	28	0	0
1976-77	13	0	0	0
1977-78	0	0	0	0
1978-79	17	0	0	0
1979-80 through 2000-01	No trapping due to lack of spring Chinook Salmon in late-spring and summer			
2001-2019	No spring Chinook Salmon trapped either early or late			

[1] Fall-trapped UKTR spring Chinook Salmon are the same brood year as the spring-trapped UKTR spring Chinook Salmon of the preceding reporting period. UKTR spring Chinook Salmon were not differentiated from UKTR fall Chinook Salmon prior to 1968-69.

6.7.4.1 Trends in UKTR fall Chinook Salmon Returns to IGH

Both long-term (1963 – 2019) and recent (12-years, 2008-2019) trends in returns to IGH were calculated. Methods were the same as those used to assess trends in natural abundance in *Section 4 Status and Trend*, of this document. Trend greater than one indicates an increase, and trend less than one indicates a decrease, in returns over the time period analyzed. The long-term trend in returns to IGH was 1.036, with 95% confidence intervals of 1.022 – 1.050. Recent trend (12-years or 4-generations) for returns to the hatchery was 0.939, with 95% confidence intervals of 0.831 – 1.062. Although the long-term trend in returns is clearly positive, the recent return trend is slightly negative suggesting that average numbers of UKTR fall Chinook Salmon returning to the hatchery may have declined over the period 2008 – 2019. However, the Department cannot conclude that a decline occurred with certainty because the confidence intervals range from below one (decline) to above one (increase).

6.7.4.2 Annual Production of UKTR fall Chinook Salmon at IGH

Annual IGH hatchery-origin Chinook Salmon inputs to the basin have been large. Between 1988 and the present, IGH released an average of 4,958,957 UKTR fall Chinook Salmon smolts and 948,468 yearlings annually (Table 6.4). Recent (10-year) average releases are 3,750,668 smolts and 982,281 yearlings. Recent annual production has been relatively stable at high release numbers. However, long term trend in UKTR fall Chinook Salmon smolt production has slightly declined over the period (high certainty; data not shown) and yearling production slightly increased (but with high uncertainty; data not shown). The notably low production of fall ecotype fingerlings in the 2017 release year was due to very low take of eggs, prompting the Department's decision to prioritize the yearling program to increase fishery contributions and returns to the hatchery (Wade Sinnen and Patrick Brock, CDFW, Personal Communication, November 2019).

6.7.4.3 Impacts of Dam Removal on IGH Hatchery Operations

Iron Gate Dam, along with three other upstream dams, are slated for removal starting in 2022 if permits are received on schedule (see *Section 7 Klamath Dam Removal*). In the process, IGH, in its current form, will become non-functional due to lack of water to the facility. Current plans contemplate modifications at IGH to continue producing fish; however, at the time of this review, plans for continued Klamath River hatchery production have not been finalized. The most recent proposal is for some fall Chinook Salmon production and all Coho Salmon production to be moved upstream to a small facility on Fall Creek (see Figure 7.1 for details) just prior to and for at least eight years post dam removal. All steelhead production, which has been very minimal in recent years, will cease at IGH. New construction and refurbishment of the Fall Creek Hatchery facility is planned. At this time, it is unknown what actual production will be at the hatcheries; however, total UKTR fall Chinook Salmon production at the smaller facility will most likely be less than current production.

6.7.5 Trinity River Hatchery

Trinity River Hatchery (TRH) was constructed in 1964 as part of the Trinity River Division of the Central Valley Project to mitigate for the loss of anadromous fish habitat above Lewiston Dam. TRH is located at rkm 177 (rm 110) near the town of Lewiston in Trinity County, California. The facility is owned by the USBR and operated by the Department. The hatchery originally produced UKTR spring and fall Chinook Salmon, Coho Salmon, steelhead, and brown trout. TRH currently produces UKTR spring Chinook Salmon, UKTR fall Chinook Salmon, steelhead, and Coho Salmon.

Table 6.4. Annual production of UKTR fall Chinook Salmon smolts and yearlings at IGH. Yearling releases typically occur in October – November and smolt releases in May – June. Data from: Patrick Brock, CDFW, November 2019.

Release year	Brood Year	Number of Smolts	Number of Yearlings	Total Releases
1988	1987	11,360,000	1,129,240	12,489,240
1989	1988	10,186,000	992,023	11,178,023
1990	1989	5,100,000	0	5,100,000
1991	1990	5,402,659	1,000,000	6,402,659
1992	1991	3,570,000	1,099,071	4,669,071
1993	1992	3,300,312	1,155,096	4,455,408
1994	1993	4,962,344	982,562	5,944,906
1995	1994	4,913,457	904,107	5,817,564
1996	1995	5,626,408	407,177	6,033,585
1997	1996	5,286,641	1,088,280	6,374,921
1998	1997	5,103,476	1,096,436	6,199,912
1999	1998	4,965,229	1,122,127	6,087,356
2000	1999	5,028,070	1,055,112	6,083,182
2001	2000	4,938,000	1,092,636	6,030,636
2002[1]	2001	4,966,640	1,087,081	6,053,721
2003	2002	5,116,165	1,083,900	6,200,065
2004[2]	2003	5,182,092	685,819	5,867,911
2005	2004	5,370,342	842,848	6,213,190
2006	2005	6,171,838	874,917	7,046,755
2007	2006	5,363,972	984,502	6,348,474
2008	2007	5,290,005	1,105,870	6,395,875
2009	2008	3,976,305	773,165	4,749,470
2010	2009	4,528,056	852,129	5,380,185
2011	2010	3,937,878	944,369	4,882,247
2012	2011	4,640,814	1,148,932	5,789,746
2013	2012	3,361,672	979,668	4,341,340
2014	2013	4,427,279	993,717	5,420,996
2015	2014	3,826,185	943,489	4,769,674
2016	2015	3,644,648	966,712	4,611,360
2017	2016	411,872	1,016,779	1,428,651
2018	2017	4,174,040	994,737	5,168,777
2019	2018	4,554,239		
average		**4,958,957**	**948,468**	**5,920,481**

Release year	Brood Year	Number of Smolts	Number of Yearlings	Total Releases
10-year average	**3,750,668**	**982,281**	**4,643,664**	

[1] 2002-2019 Fish released in groups as size threshold reached or when river temp. reached 65 °F

[2] 2004-2019 Fall Creek rearing pond facility not used

Mitigation goals for TRH, intended to mitigate for fish habitat losses due to dam construction were established based on pre-project anadromous fish population studies. Studies by USFWS/CDFG (1956) estimated that 3,000 UKTR spring Chinook Salmon and 8,000 UKTR fall Chinook Salmon spawning fish historically passed above Lewiston Dam. Annual adult production goals were established in 1980 to meet return targets (escapement plus catch) of 6,000 UKTR spring Chinook Salmon, and 70,000 UKTR fall Chinook Salmon. Current production goals for TRH UKTR Chinook Salmon are shown in Table 6.5. At the direction of NMFS, the UKTR spring Chinook Salmon smolt release window was changed from 1 – 15 June to 15 – 31 May to minimize the total number of UKTR spring and fall Chinook Salmon hatchery-origin fish released to the river at any one time, reducing competition with hatchery fish (D. Muir, CDFW, Personal Communication, November 2019).

TRH broodstock originated from collections at a weir in the Trinity River starting in 1964. The program has not used out of basin sources of eggs or broodstock for at least the last 10 years.

Table 6.5. Annual Trinity River Hatchery UKTR spring and fall Chinook Salmon production goals.

Ecotype	Green eggs	Release Type	Prod. goal	Min. size	Fecund.	Females	F:M	Release date
Spring	3,000,000	Smolts	1,000,000	90/lb	2,500	1,200	1:1	15-31 May
Spring		Yearlings	400,000	10/lb				1-15 Oct
Fall	6,000,000	Smolts	2,000,000	90/lb	2,750	2,182	1:1	1-15 Jun
Fall		Yearlings	900,00	10/lb				1-15 Oct

6.7.5.1 Broodstock History and Spawning

Currently TRH UKTR spring Chinook Salmon broodstock are collected at the hatchery's fish ladder and gathering tank (fish trap), directly below Lewiston Dam. Adults are held in-river for up to four months (June – September) until the adult trap is opened just after Labor Day. To avoid mixing spring and fall broodstock, the fish trap is closed for approximately 14 days between return seasons: approximately between 12 – 25 October of each year. UKTR fall Chinook Salmon spawning commences about the last week in October. Hatchery staff initially separate spring and fall fish by appearance. Overlap of hatchery-origin spring and fall Chinook

Salmon is also monitored by reading CWTs of fish used for spawning. If necessary, egg lots with mixed spring-fall parentage are culled prior to eye-up to maintain separation of ecotypes in the hatchery. Overlap of fall and spring Chinook Salmon occurs on both sides of the spawning break. After the 14-day closure, the trap is opened to begin collection of fall Chinook Salmon broodstock. Fall broodstock are separated from spring spawning fish by appearance.

Annual female broodstock targets are 2,182 UKTR fall Chinook Salmon females and 1,200 UKTR spring Chinook Salmon females. UKTR fall Chinook Salmon produce an average of 2,750 eggs/female, and UKTR spring Chinooks Salmon average 2,500 eggs/female. Spawning occurs two days per week for both spring and fall ecotypes. Fall Chinook Salmon may be spawned on a third day to make use of previously unripe females. The current spawning protocol is to sequentially pool gametes of four females with five males[11]. An average of 1,146 females are spawned each year to allow for culling and to meet production goals. Broodstock are mostly age-3 with some age-2 fish, rarely age-4. Table 6.6 shows the number of broodstock spawned each year.

Using proportions of CWT recoveries, hatchery staff estimate the proportion of natural-origin broodstock (pNOB) is about 0.1 (10%). All releases are volitional[12], and directly from the hatchery to the Trinity River. Annual production of Chinook Salmon at TRH is shown in Table 6.6.

6.7.5.2 Rearing, Marking/Tagging, and Release

Approximately 1.4 million UKTR spring Chinook Salmon fry are grown annually. Fish for both smolt and yearling releases are initially grouped together. For both UKTR spring and fall Chinook Salmon, there is a smolt (55 fish per pound; fpp) release 1 – 15 June, and a yearling (10 fpp) release 1 – 15 October. Both UKTR spring and fall Chinook Salmon hatchery fish are adipose fin-clipped (marked) and CWTs are applied at a rate of 25% according to the Department standard. A portion of the UKTR spring Chinook Salmon production, about 50,000 fish, are released unmarked to calibrate screw traps near Willow Creek. The yearling group, approximately 440,000 fish, is segregated from the general population prior to release. Originally, yearlings were selected from the earliest and latest egg takes. However, current

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[11] This spawning technique is known to reduce the number of males contributing to production because of sperm competition. The true proportion of males to females spawned, in terms of offspring contribution, is less than reported.

[12] Volitional release is a juvenile hatchery release practice that allows fish to leave the hatchery by choice, rather than being forced out of the hatchery at a given time. It results in more protracted emigration as fish naturally become ready to migrate to the ocean.

practice is to select the yearling group from pooled juveniles representing all pairings throughout each run.

6.7.5.3 TRH UKTR spring and fall Chinook Returns

Both UKTR spring and fall Chinook Salmon returns to TRH are generally in the thousands, with some years exceeding ten thousand annually (Figure 6.14). Table 6.6 shows annual numbers of both UKTR spring and fall Chinook Salmon since the beginning of program operation at TRH. Figure 6.15 shows the pattern of recent annual returns of UKTR Spring Chinook Salmon from 2002 – 2003 through the present.

Return trend for the TRH spring and fall Chinook Salmon programs was calculated as in *Section 4 Status and Trend*. The long-term spring Chinook Salmon return trend between 1971 – 2019 was 1.005, with 95% confidence intervals of 0.990 – 1.021. The more recent 12-year trend (2008 – 2019) was 0.928, with 95% confidence intervals of 0.857 – 1.004. Production of spring Chinook Salmon at TRH, although variable, has shown no clear pattern of increase or decrease over either monitoring period.

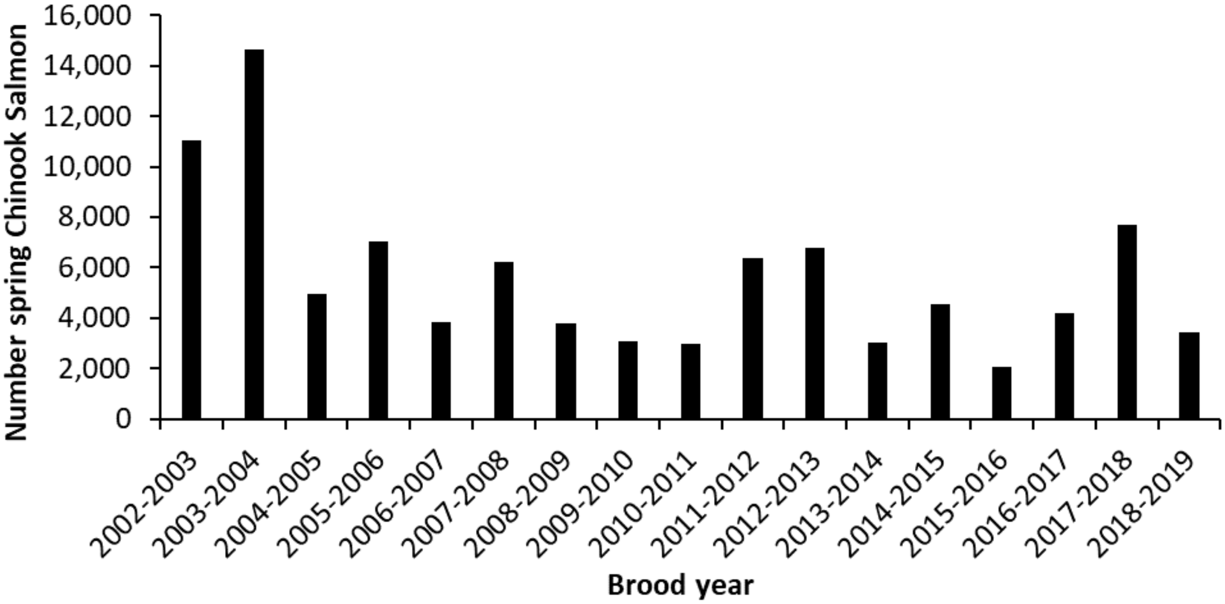

Figure 6.14. Number of UKTR spring Chinook Salmon trapped annually at Trinity River Hatchery

UKTR fall Chinook Salmon returns to TRH are variable but large, with thousands to tens of thousands of fish arriving annually (Table 6.6). Long-term (1971 – 2019) return trends for fall Chinook Salmon to TRH is 1.019, with 95% confidence intervals of 1.004 – 1.035, indicating a statistically supported slight increase in returns over the monitoring period. The 12-year trend however shows a slightly negative trend, but without statistical support. Overall, trend in fall Chinook Salmon returns to the hatchery appear to be about the same or slightly increasing.

Although a clear pattern of decline in TRH returns is not apparent in the above analysis, Sullivan and Hileman (2019), using different methods, found evidence that all age classes of marked and unmarked Chinook Salmon returning to TRH have declined in relative abundance since 2003.

Table 6.6. Annual UKTR spring and fall Chinook Salmon production at Trinity River Hatchery, 1958-59 through 2018-19 seasons. From: CDFW, TRH Annual Reports.

Season	UKTR spring Chinook Salmon: Trapped	UKTR spring Chinook Salmon: Females Spawned	UKTR spring Chinook Salmon: Fingerlings Released	UKTR spring Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Trapped	UKTR fall Chinook Salmon: Females Spawned	UKTR fall Chinook Salmon: Fingerlings Released	UKTR fall Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Notes
1958-59									1st year of operation Lewiston Trapping Station - fish moved above dam site while dam under construction.
1959-60									
1960-61	556				6,910	494	993,900		Females spawned collected Oct 1960. Fingerlings released were actually swim-up fry.

Season	UKTR spring Chinook Salmon: Trapped	UKTR spring Chinook Salmon: Females Spawned	UKTR spring Chinook Salmon: Fingerlings Released	UKTR spring Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Trapped	UKTR fall Chinook Salmon: Females Spawned	UKTR fall Chinook Salmon: Fingerlings Released	UKTR fall Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Notes
1961-62	284				5,113	831	2,427,070		284 spring Chinook Salmon trucked back to river downstream of dam site. Females spawned collected Oct 1961. Fingerlings released were actually swim-up fry.

Season	UKTR spring Chinook Salmon: Trapped	UKTR spring Chinook Salmon: Females Spawned	UKTR spring Chinook Salmon: Fingerlings Released	UKTR spring Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Trapped	UKTR fall Chinook Salmon: Females Spawned	UKTR fall Chinook Salmon: Fingerlings Released	UKTR fall Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Notes
1962-63					9,451		1,848,400		TRH operations begin 15 May 1963. "A few" spring Chinook Salmon were observed. Fingerlings released were actually swim-up fry.
1963-64			80,000		6,735	2,409	4,624,900		First spawn at TRH. Spring fingerlings are "assumed spring" from early spawns. Females spawned includes fall and assumed spring ecotypes.

Season	UKTR spring Chinook Salmon: Trapped	UKTR spring Chinook Salmon: Females Spawned	UKTR spring Chinook Salmon: Fingerlings Released	UKTR spring Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Trapped	UKTR fall Chinook Salmon: Females Spawned	UKTR fall Chinook Salmon: Fingerlings Released	UKTR fall Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Notes
1964-65			100,000		6,303	2,869	7,341,300	300,000	Spring fingerlings are "assumed spring" from early spawns. Females spawned includes fall and assumed spring ecotypes. 300,000 yearlings were in bad condition.

Season	UKTR spring Chinook Salmon: Trapped	UKTR spring Chinook Salmon: Females Spawned	UKTR spring Chinook Salmon: Fingerlings Released	UKTR spring Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Trapped	UKTR fall Chinook Salmon: Females Spawned	UKTR fall Chinook Salmon: Fingerlings Released	UKTR fall Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Notes
1965-66					3,075	930	1,300,000	224,548	Females spawned includes fall and assumed spring ecotypes. Fingerling mortality was high due to gas bubble disease.
1966-67					2,054	1,000	2,873,600	0	Females spawned includes fall and assumed spring ecotypes.
1967-68					2,870	1,164	3,758,050	52,185	Females spawned includes fall and assumed spring ecotypes.

Season	UKTR spring Chinook Salmon: Trapped	UKTR spring Chinook Salmon: Females Spawned	UKTR spring Chinook Salmon: Fingerlings Released	UKTR spring Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Trapped	UKTR fall Chinook Salmon: Females Spawned	UKTR fall Chinook Salmon: Fingerlings Released	UKTR fall Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Notes
1968-69					3,899	1,897	4,252,000	518,400	Females spawned includes fall and assumed spring ecotypes. Spring and fall not counted separately. Fingerlings said to be "mostly fall." Yearlings not separated by fall/spring.
1969-70	109	19	0	500,000	2,477	762	1,270,230	0	Hatchery records start to include some level of separation of spring and fall returns and production.

Season	UKTR spring Chinook Salmon: Trapped	UKTR spring Chinook Salmon: Females Spawned	UKTR spring Chinook Salmon: Fingerlings Released	UKTR spring Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Trapped	UKTR fall Chinook Salmon: Females Spawned	UKTR fall Chinook Salmon: Fingerlings Released	UKTR fall Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Notes
1970-71	1,847	231	0	*	2,597	455	1,665,494	75,000	Fall yearlings here are actually probably both spring and fall
1971-72	6,324	2,192	3,922,690	330,373	2,897	1,338	382,030	0	
1972-73	7,791	2,185	3,896,450	256,840	3,590	1,271	937,940	1,045,189	
1973-74	3,104	507	798,376	221,375	2,108	395	0	724,879	
1974-75	4,481	1,248	1,602,425	267,210	3,583	921	664,650	463,565	
1975-76	4,065	1,564	1,535,000	279,995	3,158	1,372	2,557,000	329,073	
1976-77	4,284	1,090	1,902,150	364,210	3,340	377	1,343,925	659,500	
1977-78	1,509	228	0	58,000	4,212	697	390,400	228,100	Fall yearlings are from Klamath R. egg transfer
1978-79	3,899	1,171	*	100,000	7,293	3,025	4,413,883	492,137	Fall fingerlings are combined spring and fall
1979-80	1,544	484	416,900	400,886	2,526	639	409,632	786,857	
1980-81	1,288	137	0	123,728	5,970	1,639	1,481,045	712,450	
1981-82	2,648	839	1,249,475	35,128	3,226	1,239	979,300	971,873	

Season	UKTR spring Chinook Salmon: Trapped	UKTR spring Chinook Salmon: Females Spawned	UKTR spring Chinook Salmon: Fingerlings Released	UKTR spring Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Trapped	UKTR fall Chinook Salmon: Females Spawned	UKTR fall Chinook Salmon: Fingerlings Released	UKTR fall Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Notes
1982-83	1,549	545	151,875	358,268	6,120	921	430,930	1,093,613	
1983-84	1,135	313	0	332,292	5,788	2,536	2,575,335	860,813	
1984-85	1,273	305	0	434,475	2,471	721	510,000	1,165,781	
1985-86	23,902	2,553	5,352,235	1,713,568	11,786	2,984	210,250	901,913	Hatchery records begin to clearly separate spring and fall returns and production.
1986-87	5,669	1,478	2,092,770	492,860	22,278	5,322	3,680,881	1,018,440	
1987-88	10,839	1,159	2,803,226	486,048	15,401	2,601	2,350,205	982,784	
1988-89	15,880	1,228	1,938,914	0	20,506	2,210	2,921,982	93,300	
1989-90	6,663	953	1,725,237	608,580	9,709	1,604	2,749,774	1,112,412	
1990-91	2,676	1,207	1,839,541	348,914	1,580	663	0	1,099,574	
1991-92	862	251	210,188	600,262	2,510	709	581,539	643,910	
1992-93	2,116	456	488,219	375,301	3,683	1,585	2,342,037	933,796	
1993-94	2,951	1,395	1,498,015	485,260	1,273	217	202,275	972,074	
1994-95	3,196	974	1,458,984	800,205	7,292	1,415	2,153,982	213,563	
1995-96	9,317	1,763	1,057,037	474,980	14,925	2,459	2,038,461	950,015	
1996-97	4,984	1,388	1,034,825	405,480	6,147	2,198	2,101,306	910,500	
1997-98	5,147	777	1,294,518	414,579	6,250	1,403	2,403,407	916,971	

Season	UKTR spring Chinook Salmon: Trapped	UKTR spring Chinook Salmon: Females Spawned	UKTR spring Chinook Salmon: Fingerlings Released	UKTR spring Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Trapped	UKTR fall Chinook Salmon: Females Spawned	UKTR fall Chinook Salmon: Fingerlings Released	UKTR fall Chinook Salmon: Yearlings Released	UKTR fall Chinook Salmon: Notes
1998-99	4,787	1,425	1,148,984	420,511	14,626	3,347	2,050,636	907,354	
1999-2000	4,222	1,657	959,019	399,134	7,169	2,049	1,991,693	993,382	
2000-01	12,192	1,000	1,093,525	390,506	27,028	1,983	2,113,804	863,267	
2001-02	6,955	1,005	1,032,548	401,743	18,200	1,809	2,084,069	872,666	
2002-03	11,063	1,192	1,005,179	425,701	4,500	1,331	2,078,192	940,049	
2003-04	14,646	1,127	1,060,735	443,686	30,509	1,996	2,103,459	908,913	
2004-05	6,563	963	724,081	436,615	13,389	2,067	2,065,329	956,688	
2005-06	7,049	1,223	1,100,718	431,380	13,380	2,988	2,099,237	965,356	
2006-07	3,833	1,118	947,501	417,165	12,241	2,502	2,021,056	965,516	
2007-08	6,036	1,376	737,929	390,136	18,114	2,474	1,065,605	1,001,176	
2008-09	3,786	1,242	940,937	424,823	5,235	2,026	2,018,580	980,211	
2009-10	3,092	1,199	662,156	442,953	7,559	2,241	1,975,162	927,141	
2010-11	2,956	1,022	733,351	412,147	8,951	1,843	1,936,149	954,382	
2011-12	6,364	927	756,709	444,873	16,346	1,897	1,836,464	858,821	
2012-13	6,801	1,303	1,045,003	364,640	17,471	2,093	1,687,329	982,968	

Season	**UKTR spring Chinook Salmon: Trapped**	**UKTR spring Chinook Salmon: Females Spawned**	**UKTR spring Chinook Salmon: Fingerlings Released**	**UKTR spring Chinook Salmon: Yearlings Released**	**UKTR fall Chinook Salmon: Trapped**	**UKTR fall Chinook Salmon: Females Spawned**	**UKTR fall Chinook Salmon: Fingerlings Released**	**UKTR fall Chinook Salmon: Yearlings Released**	**UKTR fall Chinook Salmon: Notes**
2013-14	3,035	1,144	631,583	365,787	3,965	1,544	2,118,989	988,247	
2014-15	4,530	907	967,060	436,101	6,225	1,378	1,370,831	987,100	
2015-16	2,076	824	1,000,028	101,905	3,376	1,384	1,964,041	436,674	Data for 2016-19 releases are from planting receipts from Darrick Muir, Nov 2019.
2016-17	2,104	899	1,102,711	438,256	1,557	534	0	1,028,336	Data from Darrick Muir, Nov 2019.
2017-18	1,393	645	869,305	437,909	5,613	1,923	1,983,000	1,015,946	Data from Darrick Muir, Nov 2019.
2018-19	3,449	937	823,505	395,206	7,952	2,198	2,136,438	989,713	Data from Darrick Muir, Nov 2019.
Average	**4,977**	**1,036**	**1,133,169**	**401,837**	**8,043**	**1,670**	**1,896,054**	**745,039**	
Goals			**1,000,000**	**400,000**			**2,000,000**	**900,000**	

6.7.5.4 Trinity River Hatchery Annual Production

Artificial propagation associated with TRH has been active since before the hatchery was built (Table 6.6). Current annual production goals (Table 6.5) for spring are 1,000,000 smolts and 400,000 yearlings, and for fall are 2,000,000 smolts and 900,000 yearlings. Hatchery records only clearly discriminate spring from fall production starting in the 1985 – 1986 season.

Both UKTR spring and fall Chinook Salmon releases from TRH are large. Annual releases from this hatchery are a substantial portion of the total UKTR spring Chinook Salmon productivity for the basin.

Table 6.7. Trends in UKTR spring and fall Chinook Salmon releases from Trinity River Hatchery. Note different time range for fall and spring fish. Data from CDFW, TRH Annual Reports.

	Fingerling Release Trend	Upper 95% CI	Lower 95% CI	Yearling Release Trend	Upper 95% CI	Lower 95% CI
UKTR fall Chinook Salmon 1965-2019	0.993	0.931	1.059	1.095	1.037	1.156
UKTR spring Chinook Salmon 1986-2019	0.997	0.958	0.996	1.038	0.944	1.14

6.7.5.5 Trends in UKTR spring and fall Chinook Hatchery Production

Data from the Department’s Annual Reports were used to calculate trends in annual fingerling and yearling releases of UKTR spring and fall Chinook Salmon from TRH (Table 6.7). Fingerling release trend for both hatchery-origin UKTR spring and fall Chinook Salmon has declined over time and yearling releases have increased in size; however, the changes are small and not all significant. Only UKTR fall Chinook Salmon yearling release increases and UKTR spring Chinook Salmon fingerling decreases are statistically supported. In general, production has been remarkably stable for both release types and for both ecotypes from TRH for several decades.

6.7.5.6 Trinity River Hatchery Spring and Fall Chinook Hatchery Influence

Fall Chinook Salmon hatchery production at TRH is large, whereas spring production is more modest. Additionally, both UKTR spring and fall Chinook Salmon hatchery influence is complicated by production of both smolts, with a lower early life-history survival rate, and yearlings, with a greater survival rate.

Hatchery influence from both hatcheries in the region appears to be most concentrated in the areas adjacent to the hatcheries (Table 6.8; CA HSRG 2012). Spawning survey information (observations of adipose fin-clipped fish) and genetic analyses indicate relatively low hatchery influence in areas farther from IGH and TRH. This is likely due in large part to the policy of releasing both UKTR spring and fall Chinook Salmon hatchery-origin fish at or near the hatcheries (CA HSRG 2012).

Table 6.8. Estimated proportion of hatchery-origin spawning fish (pHOS) for UKTR spring Chinook Salmon natural-area spawning fish in the Upper Trinity River above Junction City Weir and fish trapped at Trinity River Hatchery, 2002 – 2018.

Year	pHOS natural area spawning fish	pHOS at TRH
2002	0.57	0.93
2003	0.62	0.90
2004	0.59	0.92
2005	0.66	0.89
2006	0.18	0.81
2007	0.79	0.86
2008	0.28	0.83
2009	0.28	0.87
2010	0.26	0.87
2011	0.24	0.95
2012	0.53	0.88
2013	0.58	0.95
2014	0.45	0.89
2015	0.59	0.84
2016	0.12	0.95
2017	0.42	0.98
2018	0.62	0.88
Average	**0.46**	**0.89**
Min	**0.12**	**0.81**
Max	**0.79**	**0.98**

Proportionate Natural Influence (PNI) is a commonly used indicator of hatchery influence (e.g. CA HSRG 2012). A PNI of at least 0.5 ensures that the natural environment rather than the hatchery environment, is the main selective feature shaping adaptations. PNI considers the relationship of the proportion of natural-origin fish used as broodstock and the proportion of hatchery-origin fish that spawn in natural areas:

$$PNI = \frac{pNOB}{pNOB + pHOS}$$

Where *pNOB* is the proportion of natural-origin fish used as broodstock and *pHOS* is the proportion of hatchery-origin fish that spawn naturally. PNI uses numbers of hatchery and natural fish to estimate the effect of hatchery fish on natural stocks. A more advanced version of PNI, called effective *PNI* ($PNI_{effective}$, HSRG 2015), uses the actual reproductive success of hatchery and natural fish to estimate hatchery impact. Because hatchery fish often have lower reproductive success than natural-origin fish (HSRG 2015), the original PNI calculation is thought to overestimate hatchery influence.

Annual returns of hatchery-origin UKTR spring Chinook Salmon to natural spawning areas have varied greatly (Figure 6.15). Rough PNI calculations support the hypothesis that hatchery influence is greater at the hatchery than in more distant natural spawning locations. In the years 2002-2018, pHOS on the natural UKTR spring Chinook Salmon spawning grounds above Junction City Weir ranged from 0.12-0.79, with an average of 0.46. In contrast, pHOS at the hatchery itself (TRH) was much higher, ranging from 0.81-0.98, with an average of 0.89.

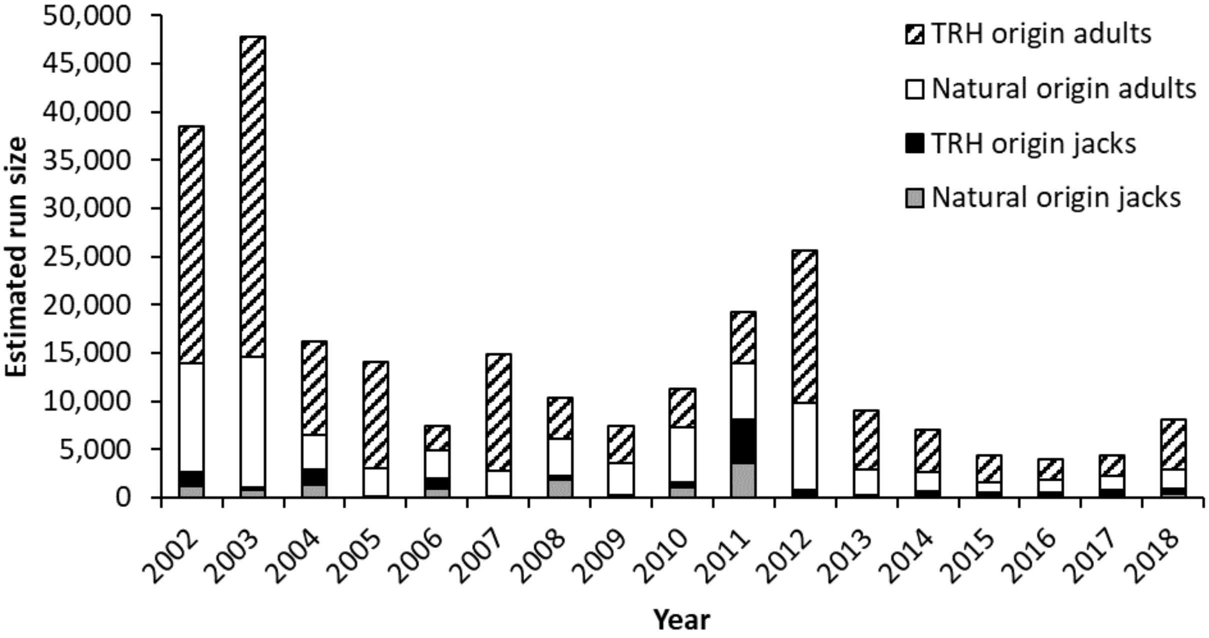

Figure 6.15. Estimated UKTR spring Chinook Salmon run-size for the Trinity River upstream of Junction City weir, 2002 – 2017, showing natural- and TRH-origin composition. Redrawn from: CDFW 2019.

Using the pHOS calculations for the UKTR spring Chinook Salmon natural spawning area above Junction City Weir and at TRH yielded a rough PNI of 0.19 for the Upper Trinity River UKTR spring Chinook Salmon population component. The target PNI for most integrated programs is ≥0.5. For most conservation programs the PNI target is higher (≥0.67) to provide additional protection for recovering populations. The Upper Trinity River UKTR spring Chinook Salmon PNI is considerably short of either target; however, concentration of hatchery fish spawning near TRH is an expected, and even desired, consequence of on-site releases. Such concentration allows for efficient broodstock collection and provides a potential mechanism for removing excess hatchery fish from the system.

Proportion of hatchery-origin fish on spawning grounds for the places where the Department has data (Tables 6.8, 6.9) show that pHOS for both spring and fall Chinook Salmon is approximately 0.5, which just meets a common target to ensure that the natural environment, not the hatchery, is the main driver of evolution in the system (CA HSRG 2012); however, for spring Chinook, in some years, pHOS is quite high, on the order 60-70%. This indicates that, although average pHOS for UKTR spring Chinook Salmon in the Upper Trinity River is reasonable over the long term, PNI in natural spawning areas near TRH can be high in some years (Figure 6.15 and Table 6.8).

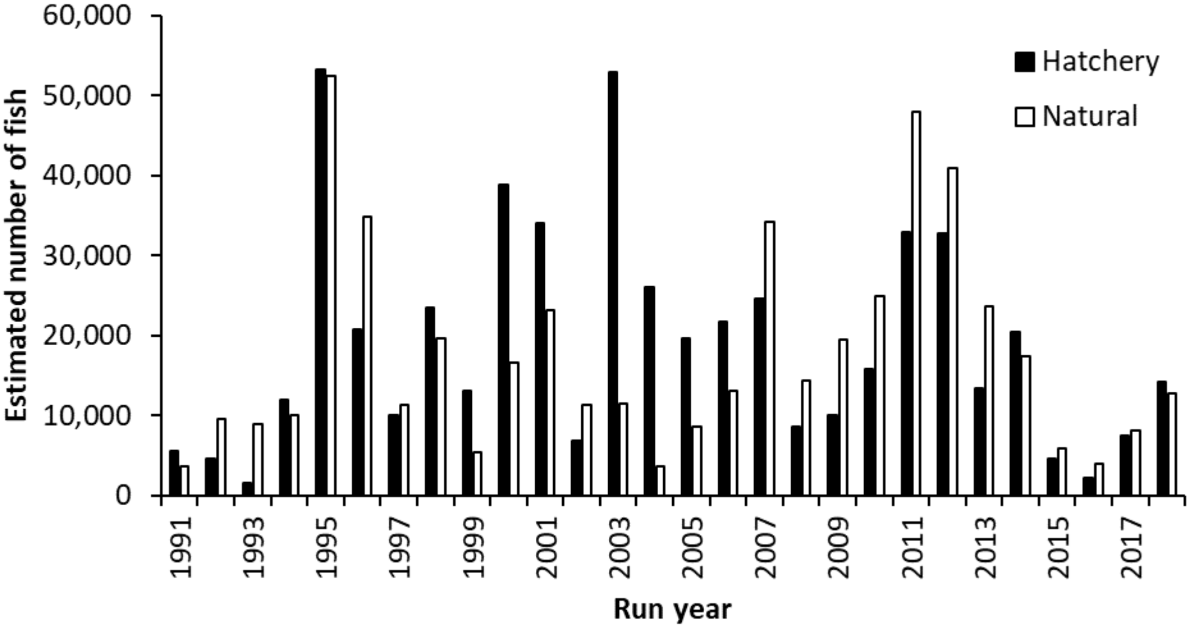

Figure 6.16. Numbers of hatchery and natural UKTR fall Chinook Salmon returns to the Trinity River above Willow Creek Weir (6.7 km upstream of the town of Willow Creek) 1991 – 2017. Redrawn from: CDFW 2019.

PNI estimates are not available for all areas where UKTR spring Chinook Salmon spawn. Because returning hatchery fish are concentrated near the hatchery, spring pHOS for distant locations (e.g., the Salmon River) is likely to be much lower, and PNI much higher than for the Upper Trinity River. Because the area over which pHOS is estimated is important to accurately assess hatchery influence, better and more complete pHOS estimates in all spring Chinook Salmon spawning aggregations are needed.

Table 6.9. Estimated contribution of Trinity River Hatchery-origin UKTR fall Chinook Salmon to the total estimated run size upstream of Willow Creek Weir, 1991 – 2010. Data from: CDFW 2019.

Year	Run size	TRH component	Natural component	% TRH composition
1991	9,207	5,597	3,610	60.80%
1992	14,164	4,651	9,513	32.80%
1993	10,485	1,499	8,986	14.30%
1994	21,924	11,880	10,044	54.20%
1995	105,725	53,263	52,462	50.40%
1996	55,646	20,824	34,822	37.40%
1997	21,347	9,977	11,370	46.70%
1998	43,189	23,536	19,653	54.50%
1999	18,516	13,081	5,435	70.60%
2000	55,473	38,881	16,592	70.10%
2001	57,109	33,984	23,125	59.50%
2002	18,156	6,884	11,272	37.90%
2003	64,362	52,944	11,418	82.30%
2004	29,534	25,956	3,578	87.90%
2005	28,231	19,674	8,557	69.70%
2006	34,912	21,768	13,144	62.40%
2007	58,873	24,633	34,240	41.80%
2008	22,997	8,585	14,412	37.30%
2009	29,593	10,072	19,521	34.00%
2010	40,792	15,853	24,939	38.90%
2011	80,818	32,875	47,943	40.70%
2012	73,666	32,735	40,931	44.40%
2013	36,989	13,371	23,618	36.10%
2014	37,829	20,463	17,366	54.10%
2015	10,365	4,531	5,834	43.70%
2016	6,196	2,188	4,008	35.30%
2017	15,450	7,393	8,057	47.90%
2018	26,848	14,111	12,737	52.60%
Average:	**36,728**	**18,972**	**17,757**	**49.90%**

6.7.6 Historically Active Small-Scale Hatcheries in the Klamath Basin

Several small-scale hatchery facilities have produced UKTR fall Chinook Salmon in the Klamath basin. None of these produced large numbers of Chinook Salmon but are included here for completeness.

Historical small-scale facilities included:

- Lower Klamath/Hunter Creek: A small facility operated between 1986 – 94 by the Yurok Tribe on the lower Klamath River. The project produced roughly 6,000 – 30,000 Chinook Salmon annually (Lara 1996, as cited in PWA 1994). Average output of the hatchery was 14,850 Chinook Salmon juveniles reared to yearling size. Broodstock were captured for several years near the mouth of Blue Creek using a gill net. Early incubation and rearing were conducted at satellite facilities, transitioning later to a single facility on Spruce Creek. Juvenile releases were mostly in Hunter Creek in the latter years of the program.
- Camp Creek/Red Cap Creek: The Karuk Tribe and the Northern California Indian Development Council (NCIDC) in cooperation with Six Rivers National Forest and the California Department of Fish and Game (Wildlife) operated a small-scale hatchery on Camp Creek near Orleans. The facility began operation in 1986 using native fall Chinook Salmon broodstock. Juveniles are released as yearlings in October. Releases were marked with maxillary clips in early years and with CWTs since 1992. The number of fish released ranged from 4,637 in 1990 to 34,976 in 1995. The total number of juvenile yearling Chinook released by the program from 1986 to 1996 was 173,323 or an average of 17,332 per year.
- Horse Linto Creek (Not within the UKTR Chinook Salmon ESU; however, released fish to the basin): This was a cooperative rearing facility [CDFG, USFS and the Pacific Coast Federation of Fishermen's Association (PCFFA)]. Operations are documented in Hillemeier and Farro (1995). The Horse Linto rearing facility has discontinued operation.

6.7.7 Inter-Basin Transfers and Stray Rates

Inter-basin transfers can result in changes in population structure and blur patterns of between population diversity. Both IGH and TRH have largely used naturally returning Chinook Salmon to the hatchery as broodstock and have released their production directly to the river at or near the hatchery.

In 1973, more than 900,000 UKTR spring Chinook Salmon juveniles from TRH were out planted in the South Fork Trinity River at Forest Glen. This effort was intended to improve returns to the South Fork Trinity after the 1964 flood. Although juvenile release locations were far from the hatchery, this translocation still represents within-basin movement (Kier and Associates 1999).

Kinziger et al. (2008a) reviewed 3,614 Klamath basin hatchery records from 1943-94. Most inter-basin transfers were less than 5,000 individuals; however, some transfers were larger. Table 6.10 shows the large transfers that would be expected to have the greatest impact on genetic structure and diversity of the receiving stock. Although transfers can influence genetic structure and between population diversity, it is unknown how these specific transfers affected those traits.

Some juvenile releases involved translocation from the Upper basin to the estuary. Kinziger et al. (2008a) noted that this practice could increase straying and potentially reduce between population genetic diversity.

Table 6.10. Large inter-basin transfers in the Klamath-Trinity basin. TRH is Trinity River Hatchery. IGH is Iron Gate Hatchery. TRH+IGH indicate mixed stocks of unknown proportions. From: Kinziger et al. 2008a Table 1, with modification.

Hatchery Source	Year	Run	Propagation Location	Release location	Number released
TRH and IGH	1971-77	Fall	TRH	Trinity River	1,891,594
TRH and IGH	1973	Fall	TRH	South Fork Trinity River	930,900
IGH	1975, 83, 85, 86	Fall	IGH	South Fork Salmon River	100,726
TRH	1976	Fall	TRH	Klamath River (Klamath Glen, near estuary)	819,000
IGH	1975-77, 1983-85	Fall	IGH	Klamath River (Klamath Glen, near estuary)	7,143,348

As noted in a previous section, hatchery influence on natural stocks is concentrated in natural spawning areas adjacent to IGH and TRH. Low hatchery influence in major portions of the Klamath-Trinity in places distant from hatcheries is indicated by few observations of hatchery-origin (i.e., adipose fin-clipped) fish on spawning grounds. Rupert et al. (2017) found that natural-origin Chinook Salmon spawn throughout the mainstem Trinity River whereas hatchery origin fish spawn almost entirely within the two reaches below Lewiston Dam. Genetic analyses (Williams et al. 2013; Kinziger et al. 2008a) also suggest that hatchery fish introgression with natural stocks is generally low.

CWT returns in the South Fork Trinity River from 1985 – 1995 found evidence of straying of fish from some of the small-scale hatchery rearing facilities (Table 6.11; PWA 1994). Strays were from Horse Linto Creek, Hoopa Lower Trinity River project, and Lower Klamath Rearing Project. Stray estimates using these small numbers ranged from relatively low (about 4%) to relatively high (close to 30%). Fish from some of these projects also returned to IGH. The Camp Creek Project did not show evidence of straying within the basin. These small-scale hatcheries are no longer producing fish, so they are not current factors affecting UKTR Chinook Salmon.

Table 6.11. Stray rates of hatchery UKTR fall Chinook Salmon into the South Fork Trinity River basin (1984 – 1990). Small scale hatcheries include Hoopa Fisheries, Horse Linto Creek, and Cappell Creek Hatchery.

				Origin	Origin	Origin	Origin
Year	No. fish	No. strays	total % strays	% Unknown	% TRH	% IGH	% Small scale hatcheries
1984	73	21	28.8	24.7	4.1	0.0	0.0
1985	176	42	23.8	0.0	11.3	11.4	1.1
1986	264	10	3.8	0.0	3.4	0.4	0.0
1987	455	95	21.0	0.0	18.3	0.3	2.4
1988	368	55	15.0	0.0	4.9	0.0	10.1
1989	52	5	9.6	0.0	0.0	0.0	9.6
1990	223	9	4.0	0.0	0.0	0.0	4.0

6.8 Genetic Diversity

As described in *Section 4.5.6 Diversity*, maintenance of within and between population genetic diversity in natural stocks is important to the overall protection of a species. UKTR spring Chinook Salmon exist as an ecotype of the combined UKTR Chinook ESU. As such they are an important diversity element that was once more widely distributed and more abundant than currently. Both ecotypes are necessary to viability of the UKTR Chinook salmon ESU. UKTR spring Chinook Salmon spawning aggregations are currently concentrated in the Upper Trinity River, the Salmon River, and the South Fork Trinity River, with scattered very small numbers in smaller tributaries of both the Klamath and Trinity rivers. Of the three larger escapement groups, the South Fork Trinity and Salmon River groups exist as small (10s-100s), fragmented runs (see *Section 4 Status and Trend*). The Upper Trinity River UKTR spring Chinook Salmon run is, by contrast, much larger (1000s). Small population size in the Salmon and South Fork Trinity groups, and overall fragmentation of spawning aggregations of the spring ecotype, is of concern from the standpoint of diversity loss; however, the ESU as a whole exists in large numbers throughout the basin.

6.9 Predation

Predation is not thought to be a primary factor in the decline of UKTR spring or fall Chinook Salmon and does not likely considerably affect the ability of either ecotype to survive and reproduce. Predators of juvenile Chinook Salmon include avian species (e.g., cormorants, gulls, terns, mergansers, egrets, herons, and osprey), native fish (e.g., sculpin, steelhead) and introduced species (e.g., catfish, shad, black bass). Brown Trout (*Salmo trutta*) are the most important non-native predator in the Trinity River. Large marine mammals [e.g., Pacific harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), and killer whales (*Orcinus orca*)] are known to prey on adult salmon. Predation is a natural phenomenon that can be increased to unsustainable levels by human activities such as hard in-river structures (e.g., diversions, bridge abutments, docks, riprap banks), changes in water management that lead to warmer water temperatures, introduction of non-native predator species, and habitat modification.

Warmer water temperatures, loss of habitat complexity associated with riparian vegetation and in-channel wood, and other habitat degradation may have increased predation on juvenile UKTR spring Chinook Salmon as compared to historical levels. However, the Department does not know of any comprehensive studies assessing the relative importance of this threat to UKTR spring Chinook Salmon (NRC 2004). The effects of predation are thought to be minor compared to other impacts, as there are few non-native predator species of UKTR Chinook Salmon in the basin. It has been suggested that hatchery released salmon may prey on natural salmon (e.g., ISAB 2005, as cited in Karuk Tribe and Salmon River Restoration Council 2018). However, the Department does not know of any targeted studies evaluating whether this is a significant effect in the Klamath basin.

Salmon in the Klamath basin evolved with pinniped predators such as California sea lions and Pacific harbor seals, and predation by pinnipeds is not thought to be a major factor in the decline of UKTR spring Chinook Salmon. However, pinniped populations along the California coast are currently large in relation to historic numbers (Laake et al. 2018), and a large population of pinnipeds feeding on salmonids may have a disproportionate effect on small, depressed salmon runs (NMFS 1997). In a 1997 Report to Congress, NMFS (1997) reported that pinniped predation is a potential concern for UKTR spring Chinook Salmon, but that more studies are needed to quantify the level of impact. A 1997-1998 assessment of pinniped predation (Hillemeier 1999, Williamson and Hillemeier 2001) found that some adult UKTR spring Chinook Salmon returning to the estuary were consumed by California sea lions, harbor seals, and Stellar sea lions (*Eumetopias jubatus*). Based on CWT recoveries, several hundred UKTR spring Chinook Salmon from TRH were consumed each year of the study. Although the studies were not designed to specifically evaluate impacts on UKTR spring Chinook Salmon, genetic analyses of scat samples of Pacific harbor seals in the spring of 1998 suggested that salmonids (genus *Oncorhynchus)* make up a small but perhaps significant percentage of the seals' diet, more in the spring than in the fall (Williamson and Hillemeier 2001). CDFW monitored salmonid predation by harbor seals in the lower Klamath River during seining and tagging of adult salmonids between 1984 and 1988, finding that the percentage of seined fish taken by seals ranged from 3.1-5.5% and was relatively constant from year to year (Stanley and Shaffer 1995). This percentage was similar to the expanded salmonid mortality calculated by Williamson and Hillemeier (2001) of approximately 2%. While the results of these evaluations do not specifically quantify the effects of pinniped predation on UKTR spring Chinook Salmon, they suggest that while it may be an added stressor, pinniped predation alone does not considerably affect the ability of the UKTR Chinook Salmon ESU to survive and reproduce.

6.10 Competition

Demonstrating competition is difficult because it requires that one or more resources be limiting, and evidence that competition for those resources produce a niche shift in one or both species (Hearn 1987). Native salmonids, including Rainbow Trout (steelhead), Chinook and Coho salmon, in the Klamath basin evolved and have persisted together for many thousands of years. Salmonids employ variation in reproductive and emergence timing and spatial segregation to avoid and minimize interspecific competition.

Large annual releases of hatchery-origin UKTR fall Chinook Salmon and more modest numbers of UKTR spring Chinook Salmon from IGH and TRH may result in in-river intraspecific competition with natural-origin UKTR Chinook Salmon in the basin, especially for space and thermal refugia (NMFS 2010); however, specific competitive interactions and their effects on natural-origin survival and reproduction are not known.

Non-native salmonids such as Brook Trout (*Salvelinus fontinalis*) and Brown Trout are known to compete and often displace native Redband Trout (*O. mykiss ssp.*) and Bull Trout (*S. confluentus*) from basin streams. These species, as well as other native salmonids (e.g., Rainbow Trout, Coho Salmon) may, to some small extent, compete with UKTR Chinook Salmon when times and areas overlap. However, the effects of these and many of the other invasive species in the basin are uncertain, as little quantitative information exists to evaluate their possible impacts (ESSA 2017).

6.11 Fishing

Klamath River fall Chinook Salmon are managed for a conservation floor escapement target of 40,700 natural area adults annually. The overall harvest rate is determined by the Pacific Fishery Management Council (PFMC), with NMFS guidance, on an annual basis resulting in impact rates to the stock that are designed to achieve the conservation escapement target. Ocean fisheries are structured by season (time and area) and in-river fisheries by quotas to target the overall impact rate cap. In-river harvest, both recreational and tribal are governed by quotas determined by the PMFC that target in-river escapement objectives. Tribal quotas tend to be higher than in-river sport quotas because most of the non-tribal allocation is apportioned to ocean fisheries.

6.11.1 Commercial Fishery Harvest Indices by Stock and Time-Area

The commercial ocean salmon fishery harvests the majority of both UKTR Spring Chinook Salmon produced by the Trinity River Hatchery, and UKTR fall Chinook Salmon which are included in the larger Klamath River Fall Chinook (KRFC) stock[13]. The spring ecotype generally experiences lower harvest indices compared to the fall ecotype (Figure 6.17), similar to the trend seen in the recreational fishery (Figure 6.18). Unsurprisingly, most harvest of both stocks occurs around the stocks' origin in the Klamath Management Zone and Fort Bragg; however, the Central Oregon (Florence, OR, to Humbug Mountain) Management Zone has the highest TRH UKTR spring Chinook Salmon harvest index, driven primarily by a relatively higher harvest index in September. Management areas farther from the Klamath-Trinity basin exhibit lower harvest indices of both stocks (e.g., Cape Falcon to Florence, OR, and the area south of Point Arena).

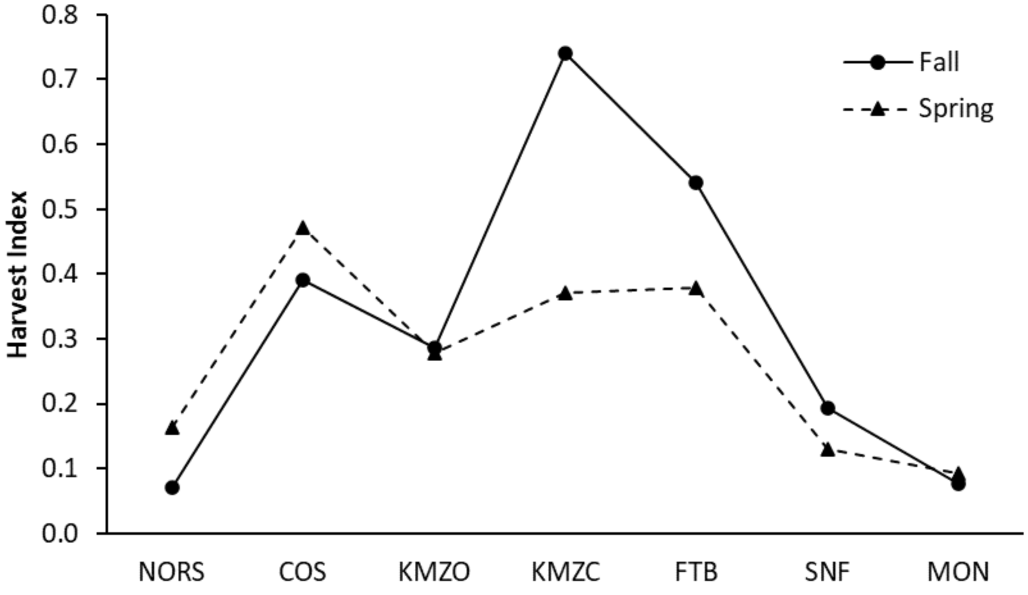

Figure 6.17. Spatial pattern in relative harvest of Trinity River Hatchery UKTR spring Chinook Salmon (dashed line) and UKTR fall Chinook Salmon (KRFC) (solid line) in the ocean commercial fishery. North (left) to South (right). Management zone abbreviations as in Table 7.1.

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[13] The KRFC stock includes UKTR fall Chinook Salmon with a very small contribution of fall Chinook Salmon from the Southern Oregon/Northern California Coast ESU in the lower Klamath River. In this report "UKTR fall Chinook Salmon (KRFC)" is used to refer to fish included in this mixed stock that are likely to be of UKTR origin.

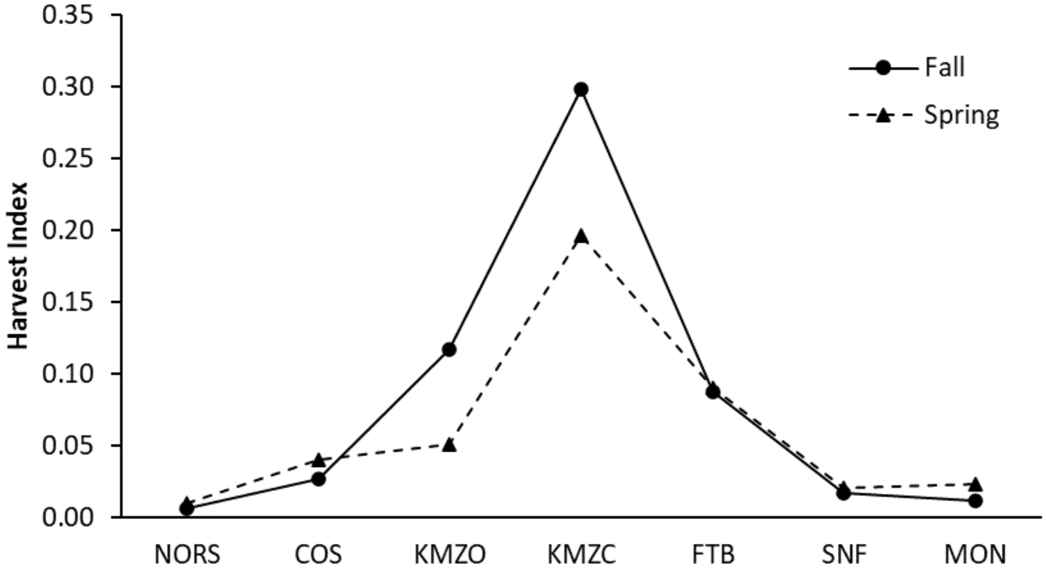

Figure 6.18. Spatial pattern in relative harvest of Trinity River Hatchery UKTR spring Chinook Salmon (dashed line) and UKTR fall Chinook Salmon (KRFC) (solid line) in the ocean recreational fishery. North (left) to South (right). Management zone abbreviations as in Table 7.1

Overall, commercial harvest indices of TRH UKTR spring and UKTR fall Chinook Salmon (KRFC) are comparable in all management areas coast-wide, suggesting the spatial distribution of these two stocks is similar, though the spring ecotype may display a more northerly distribution extension as indicated by slightly higher spring indices compared to fall in the areas north of Humbug Mountain, Oregon.

While season total harvest indices of stocks are similar, there are several time-areas where the harvest index of TRH UKTR spring Chinook Salmon exceeds that for UKTR fall Chinook Salmon (KFRC)(Tables 6.12, 6.13). Unsurprisingly, harvest indices across months demonstrate seasonality. For example, TRH UKTR spring Chinook Salmon harvest indices were elevated above UKTR fall Chinook Salmon (KFRC) harvest indices in spring months (April – May), declined below UKTR fall Chinook Salmon (KFRC) harvest indices during the summer, before increasing again in the fall. The fall increase is presumably due to recruitment of the next age-class of TRH UKTR spring Chinook Salmon into the fishery at a time when mature UKTR fall Chinook Salmon (KFRC) were leaving the ocean to spawn.

Table 6.12. Trinity River Hatchery UKTR spring Chinook Salmon ocean commercial catch per unit effort per 1 million released smolts by management area and month, brood years 1995 – 2012.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Cape Falcon-Florence S. Jetty	0.43	0.18	0.11	0.06	0.02	0.08	0.38	0.37	
Florence S. Jetty-Humbug Mtn.	0.97	0.53	0.37	0.20	0.13	0.44	1.40	0.54	
Humbug Mtn.-OR/CA Border			0.47	0.41	0.35	0.39	0.37		
OR/CA Border-Horse Mtn.			1.10	0.47	0.43	0.30	0.32		
Horse Mtn.-Pt. Arena		0.79	0.79	0.11	0.37	0.25	0.51		
Pt. Arena-Pigeon Pt.		0.19	0.40	0.20	0.09	0.02	0.02	0.02	
Pigeon Pt.-South			0.16	0.04	0.02				

Table 6.13. UKTR fall Chinook Salmon (KRFC) ocean commercial catch per unit effort per 1 million released smolts by management area and month, brood years 1995 – 2012

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Cape Falcon-Florence S. Jetty	0.32	0.05	0.04	0.03	0.06	0.10	0.11	0.12	
Florence S. Jetty-Humbug Mtn.	0.47	0.25	0.11	0.16	0.41	1.20	0.45	0.14	0.02
Humbug Mtn.-OR/CA Border			0.24	0.32	0.39	0.63	0.50		
OR/CA Border-Horse Mtn.			1.22	1.23	0.78	0.50	0.70		
Horse Mtn.-Pt. Arena		0.12	0.57	0.58	1.01	0.41	0.13		
Pt. Arena-Pigeon Pt.			0.21	0.49	0.30	0.05	0.01	0.003	
Pigeon Pt.-South			0.07	0.10	0.09	0.005			

The Fort Bragg management area between Horse Mountain and Point Arena during April experienced a relatively higher TRH UKTR spring Chinook Salmon harvest index than UKTR fall Chinook Salmon (KRFC); however, only one year of data (2007) was available to inform this analysis. The San Francisco management area also experienced a higher TRH UKTR spring Chinook Salmon harvest index during April, though this time-area is no longer available to commercial fisheries because of ESA constraints on Sacramento River winter Chinook Salmon. During May commercial fisheries, TRH UKTR spring Chinook Salmon harvest indices are higher than UKTR fall Chinook Salmon (KRFC) in all management areas coastwide, though only by a small margin in some areas. During September fisheries, the TRH UKTR spring Chinook Salmon harvest indices are greater than UKTR fall Chinook Salmon (KRFC) in northern and central Oregon, and in the Fort Bragg management area; however, UKTR fall Chinook Salmon (KRFC) harvest index exceeds that for TRH UKTR spring Chinook Salmon in the Klamath Management

Zone in both states, possibly due to harvest on the Trinity River fall Chinook Salmon component of KRFC, which has a later average maturity date (O'Farrell et al. 2010).

6.11.2 Recreational Fishery Harvest Indices by Stock and Time-Area

Harvest indices in the recreational ocean salmon fisheries are lower relative to commercial harvest indices for both TRH UKTR spring Chinook Salmon and UKTR fall Chinook Salmon (KFRC). Seasonal total harvest indices for TRH UKTR spring Chinook Salmon are generally similar to UKTR fall Chinook Salmon (KRFC), although lower in most areas. TRH UKTR spring Chinook Salmon harvest indices in the areas between Florence, OR, and Humbug Mountain and South of Pigeon Point were slightly higher than UKTR fall Chinook Salmon (KRFC), though very similar and small (approaching zero). The highest TRH UKTR spring Chinook Salmon harvest indices occurred nearest the Klamath-Trinity basin in the Klamath Management Zone between Humbug Mountain, OR, and Horse Mountain, CA. Central Oregon was the only management area where TRH spring Chinook Salmon harvest indices exceeded UKTR fall Chinook Salmon (KRFC) indices in every month of the fishery (Tables 6.14, 6.15), though the harvest indices are low relative to the Klamath Management Zone or Fort Bragg. Recreational fishery harvest indices also demonstrated seasonality, with TRH spring Chinook Salmon harvest indices generally higher in the spring months, dipping during the summer and increasing in September; however, the variation is less dramatic than the commercial fishery.

6.11.3 Ocean Harvest

In 2006, commercial salmon fishing was closed in the Klamath Management Zone because of a weak UKTR Chinook Salmon stock. In addition, the commercial fishing season along the Oregon coast was severely curtailed (USDI et al. 2012). Weak returns were believed, in part, to result from a large kill of adult spawning fish in the Klamath River between 20 – 27 September 2002. The federal government declared 2002 to be a fishery disaster and released $60 million in relief funds to help compensate losses to commercial fishermen and fishing related businesses in Oregon and California (Upton 2011).

Table 6.14. Trinity River Hatchery UKTR spring Chinook Salmon ocean recreational catch per unit effort per 1 million released smolts by management area and month, brood years 1995 – 2012.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Cape Falcon-Florence S. Jetty				0.017	0.008	0.002	0.012	0.026	
Florence S. Jetty-Humbug Mtn.			0.093	0.021	0.035	0.043	0.060	0.100	
Humbug Mtn.-OR/CA Border			0.076	0.148	0.054	0.022	0.083		
OR/CA Border-Horse Mtn.			0.388	0.329	0.110	0.070	0.162		
Horse Mtn.-Pt. Arena			0.146	0.202	0.064	0.033			
Pt. Arena-Pigeon Pt.		0.071	0.061	0.035	0.007	0.007			
Pigeon Pt.-South	0.047	0.021	0.047	0.020	0.006				

Table 6.15. UKTR fall Chinook Salmon (KRFC) ocean recreational catch per unit effort per 1 million released smolts by management area and month, brood years 1995 – 2012.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Cape Falcon-Florence S. Jetty			0.002	0.001	0.003	0.013	0.011	0.004	
Florence S. Jetty-Humbug Mtn.				0.004	0.023	0.033	0.048	0.044	
Humbug Mtn.-OR/CA Border			0.016	0.037	0.102	0.187	0.272	0.012	
OR/CA Border-Horse Mtn.			0.222	0.298	0.357	0.302	0.249		
Horse Mtn.-Pt. Arena		0.007	0.062	0.148	0.105	0.062			
Pt. Arena-Pigeon Pt.		0.028	0.040	0.036	0.016	0.003			
Pigeon Pt.-South	0.008	0.018	0.015	0.005	0.003				

The UKTR fall Chinook Salmon (KRFC) stock was declared overfished in 2018 by the Pacific Fishery Management Council. Currently, the stock remains classified as “overfished” prompting the Council to adopt a rebuilding plan. The rebuilding plan includes application of the current UKTR fall Chinook Salmon KRFC harvest control rule to set maximum allowable exploitation rates and minimum escapement values based on forecasted abundance. Although natural area escapement in 2020 was much less than the spawning fish abundance at maximum sustainable yield (S_{MSY}) of 40,000, escapement was still approximately 20,000 adults. Low escapement has been observed in the last four years. Exploitation rates have generally been at or below preseason projections. Poor ocean conditions are implicated for at least some of the observed decline (Thom 2020).

All Chinook Salmon ocean fisheries off the California coast are “mixed-stock fisheries,” meaning that Chinook Salmon from different locations and different ESUs co-occur in the ocean, and are therefore mixed in harvest, in various proportions depending on the stock, time of year, and geographic location. Different Chinook Salmon stocks (e.g., UKTR spring and fall Chinook Salmon, CV Chinook Salmon) are externally alike in appearance, and the specific stock to which any given fish belongs cannot determined at the time of harvest. Stock-identification of ocean harvested fish is limited to evaluation of CWTs recovered from hatchery-origin fish during standardized, long-term, and coastwide ocean fishery monitoring programs.

The Department evaluated information on UKTR spring Chinook Salmon ocean distribution and harvest using coded-wire tags from recovered Trinity River Hatchery-produced UKTR spring Chinook Salmon. Unfortunately, spawning age-composition and cohort reconstruction analyses necessary to estimate total ocean abundance and natural-origin harvest are currently unavailable for UKTR spring Chinook Salmon. While total ocean impacts on the stock are unknown, harvest of TRH UKTR spring Chinook Salmon can be used to evaluate minimum ocean fishery effects on the stock. However, although TRH has released tagged UKTR spring Chinook Salmon since at least 1976 (Table 6.16), interannual variation in fish released and proportion tagged make accurate evaluation over the entire period difficult. A description of the methods used in this section can be found in Appendix B.

Trinity River Hatchery has released CWT tagged spring Chinook Salmon annually since at least 1976 (Table 6.16); however, there is considerable interannual variation in the total number of fish released and the proportion tagged until 1995. For example, a little over 35,000 spring Chinook Salmon were released at a 98% CWT tag rate in 1980, followed by over 1.6 million released at a 17% tag rate the following year.

Ocean salmon fisheries on average harvested 0.1% (range: 0-0.39%) of the total released TRH spring Chinook Salmon annually for brood years 1995 – 2012 (ocean harvest years 1997 – 2017). Approximately 82% of the total ocean harvest occurred in the commercial fishery for broods 1995 – 2012 (complete broods marked and tagged at comparable rates, 86% long-term), with an equal split between Oregon and California harvest (50.5% Oregon, 49.5% California). The remaining 18% of UKTR spring Chinook Salmon harvested were taken by the recreational Salmon fishery, with over three quarters (77%) taken in California waters for broods 1995 – 2012 (14% long-term).

Ocean salmon fishery harvest of natural-origin UKTR spring Chinook Salmon is currently unavailable due to the lack of spawning age-composition and cohort reconstruction analyses. Those analyses would also be required as a prerequisite for determining ocean abundance of UKTR spring Chinook Salmon and total ocean fishery impacts (i.e., hatchery- and natural-origin harvest and incidental mortality associated with fisheries).

Table 6.16. Upper Klamath-Trinity River spring Chinook Salmon coded-wire tag releases from Trinity River Hatchery and ocean harvest; brood years 1976 – 2015[a].

Brood Year	Number Tagged	Total Released	Percent Tagged	Subtotal – Commercial OR	Subtotal – Commercial CA	Subtotal – Recreational OR	Subtotal – Recreational CA	Total Ocean Harvest [b] Com.	Total Ocean Harvest [b] Rec.	Total Ocean Harvest [b] Total	Proportion Harvested
1976	56,840	58,000	98%	139	408	3	6	547	8	556	0.96%
1977	95,230	100,000	95%	75	174	6	3	249	9	258	0.26%
1978	702,821	1,591,546	44%	801	3400	146	67	4,201	213	4,414	0.28%
1979	490,888	540,440	91%	1296	2122	141	174	3,418	316	3,734	0.69%
1980	34,601	35,128	98%	24	57	25	11	81	36	117	0.33%
1981	281,272	1,607,743	17%	173	374	80	107	547	187	734	0.05%
1982	242,655	484,167	50%	816	606	70	274	1,423	345	1,768	0.37%
1983	90,293	318,132	28%	2840	3687	238	298	6,526	536	7,063	2.22%
1984	98,568	563,970	17%	6372	6617	1120	760	12,989	1,880	14,869	2.64%
1985	293,578	3,789,170	8%	6912	9766	645	1295	16,678	1,940	18,618	0.49%
1986	298,143	1,485,468	20%	1799	1336	177	490	3,135	667	3,802	0.26%
1987	185,718	2,555,300	7%	155	118	43	107	272	150	422	0.02%
1988	280,518	2,547,494	11%	0	84	0	76	84	76	160	0.01%
1989	288,968	2,074,151	14%	68	57	22	0	124	22	146	0.01%
1990	291,547	2,961,379	10%	29	173	31	131	202	162	364	0.01%
1991	309,074	585,489	53%	0	33	9	3	33	12	45	0.01%
1992	324,994	973,479	33%	546	711	67	440	1,258	507	1,764	0.18%
1993	333,581	2,300,827	14%	224	853	94	201	1,076	295	1,372	0.06%
1994	226,727	1,934,581	12%	204	112	43	54	316	97	413	0.02%
1995	298,152	1,471,630	20%	248	70	16	80	317	96	414	0.03%
1996	329,211	1,451,117	23%	124	42	0	46	167	46	213	0.01%
1997	356,662	1,719,651	21%	927	1356	29	387	2,282	416	2,698	0.16%

Brood Year	Number Tagged	Total Released	Percent Tagged	Subtotal – Commercial OR	Subtotal – Commercial CA	Subtotal – Recreational OR	Subtotal – Recreational CA	Total Ocean Harvest [b] Com.	Total Ocean Harvest [b] Rec.	Total Ocean Harvest [b] Total	Proportion Harvested
1998	314,570	1,563,206	20%	241	141	22	115	381	137	518	0.03%
1999	282,910	1,334,212	21%	1987	1121	130	283	3,107	413	3,520	0.26%
2000	360,767	1,513,728	24%	1740	3643	123	412	5,382	535	5,918	0.39%
2001	357,615	1,460,536	24%	1967	1603	231	391	3,570	622	4,193	0.29%
2002	350,893	1,430,052	25%	1595	864	239	470	2,459	708	3,168	0.22%
2003	371,656	1,514,406	25%	213	135	12	166	348	178	526	0.03%
2004	360,662	1,544,949	23%	143	218	116	352	361	468	829	0.05%
2005	370,715	1,532,096	24%	0	0	0	0	0	0	0	0%
2006	330,477	1,364,666	24%	109	6	0	0	115	0	115	0.01%
2007	274,084	1,125,081	24%	188	62	23	23	250	46	296	0.03%
2008	333,967	1,367,340	24%	58	64	24	34	122	58	180	0.01%
2009	269,877	1,105,109	24%	278	633	84	460	912	544	1,456	0.13%
2010	265,830	1,140,452	23%	736	295	23	239	1,031	261	1,292	0.11%
2011	264,976	1,202,411	22%	315	397	9	44	712	53	765	0.06%
2012	361,576	1,525,916	24%	46	53	0	18	99	18	116	0.01%
2013[c]	362,633	1,519,977	24%	21	26	0	11	48	11	59	NA
2014[d]	348,977	1,477,842	24%	0	13	18	28	13	46	59	NA
2015[e]	357,601	1,517,947	24%	0	0	0	17		17	17	NA

[a] Recoveries from all ocean areas, including north of Cape Falcon, OR.

[b] Recoveries expanded for hatchery tagging and sample rates.

[c] Incomplete brood. Age-5 recoveries not available.

[d] Incomplete brood. Age-4 and age-5 recoveries not available.

[e] Incomplete brood. Age-3, age-4, and age-5 recoveries not available.

The Department evaluated ocean fishery harvest of TRH hatchery-origin UKTR spring Chinook Salmon using CWT data (see UKTR spring Chinook Salmon ocean distribution). Recoveries expanded for the proportion of total released fish that were CWT tagged and adipose fin-clipped and sample rate (the proportion of the fishery by time and area that was observed) were summarized by ocean salmon fishery management area as described in PFMC's salmon Fishery Management Plan (FMP).

To inform an overall perspective of ocean salmon fishery harvest, the cumulative harvest of UKTR spring Chinook Salmon was summarized for brood years 1995 through 2012 (18 broods) across 21 harvest years (1997 – 2017). For aggregate brood years 1995 – 2012, the majority of hatchery-origin UKTR spring Chinook Salmon were taken by commercial ocean salmon fisheries (83%, Table 6.17), half of which occurred in Oregon primarily between Florence South Jetty and Humbug Mountain (Coos Bay area; 66% of Oregon commercial harvest). In California, the troll fisheries between Horse Mountain (near Shelter Cove, Humboldt County) and Pigeon Point (San Mateo County) harvested the majority of UKTR spring Chinook Salmon (80% of California commercial harvest), with approximately 38% harvested in the area between Horse Mountain and Point Arena (Fort Bragg management area) and 42% between Point Arena (Sonoma County) and Pigeon Point (San Francisco management area). Relatively few UKTR spring Chinook Salmon were commercially harvested in the Klamath Control Zone between Humbug Mountain, OR and Humboldt South Jetty, likely due to limited fishing opportunity in this area because of constraints intended to protect UKTR fall Chinook Salmon (KRFC) and/or California coastal Chinook Salmon.

Table 6.17. Cumulative UKTR spring Chinook Salmon harvest and proportion of all-stocks by ocean fishery, management area, and state; brood years 1995 – 2012.

Management area	Commercial Harvest	Commercial Prop.	Recreational Harvest	Recreational Prop.	Total Harvest	Total Prop.
Cape Falcon-Florence S. Jetty	3,074	0.23%	154	0.14%	3,228	0.22%
Florence S. Jetty-Humbug Mtn.	6,999	0.67%	391	0.32%	7,390	0.63%
Humbug Mtn.-OR/CA Border	499	0.66%	347	0.37%	846	0.50%
Oregon subtotal	10,571	0.43%	893	0.27%	11,464	0.41%
Proportion OR	50%		20%		45%	
OR/CA Border-Horse Mtn.*	378	0.39%	1,656	0.65%	2,033	0.58%
Horse Mtn.-Pt. Arena	4,055	0.45%	780	0.33%	4,835	0.42%
Pt. Arena-Pigeon Pt.	4,554	0.19%	659	0.06%	5,213	0.15%
Pigeon Pt.-South	1,716	0.16%	425	0.09%	2,141	0.14%
California subtotal	10,702	0.24%	3,520	0.17%	14,222	0.22%
Proportion CA	50%		80%		55%	
Total	21,273	0.30%	4,412	0.19%	25,686	0.27%
Total	82.8%		17.2%			

* OR/CA Border to Humboldt South Jetty for commercial fisheries.

The ocean recreational fishery contributed the remaining 17% of cumulative UKTR spring Chinook Salmon harvest for brood years 1995 – 2012, primarily in California (80%), and specifically in the area between the OR/CA Border and Horse Mountain (38% of the total harvest), an area encompassing the Klamath River.

Hatchery-origin UKTR spring Chinook Salmon are not a target stock for ocean salmon fisheries and contribute less than 1% to total (all-stocks) salmon harvest in all ocean management areas and fisheries. Overall, hatchery-origin UKTR spring Chinook Salmon contribute 0.27% to total ocean salmon harvest south of Cape Falcon, OR, 0.22% in California and 0.41% in Oregon south of Cape Falcon.

While cumulative harvest of UKTR spring Chinook Salmon from brood years 1995 – 2012 can provide a high-level overview of ocean salmon fisheries, it is confounded by variable annual amounts of fishing opportunity overall and opportunity among management areas. Ocean salmon fishing opportunity and total harvest of all stocks varies considerably based on annual management objectives, geographic location of open areas, and the time of year available to fishing.

Interannual harvest of UKTR spring Chinook Salmon varied between brood years 1995 – 2012, potentially as a result of inconsistent ocean salmon fishery regulations geographically and by time of year. The Department evaluated the potential influence of variable days open to fishing, UKTR spring Chinook Salmon catch per day and found no relationship in either commercial (Figure 6.19, R^2=0.09) or recreational (Figure 6.20, R^2=0.25) ocean salmon fisheries, suggesting that UKTR spring Chinook Salmon are not equally distributed in time and/or space, and finer scale stratification is likely warranted. This analysis found similar results when it compared UKTR spring Chinook Salmon harvest to total days fished (i.e. fishing pressure), further showing that time on the water (fishing opportunity) alone is not a good indicator of potential UKTR spring Chinook Salmon harvest in the absence of a time-area-fishery-specific analysis.

In the commercial ocean salmon fisheries, harvest of UKTR spring Chinook Salmon ranged from less than one fish per 1,000 total Chinook Salmon harvested up to 28 UKTR spring Chinook Salmon per 1,000 all stocks (Table 6.18). Several of the open areas and times in this analysis had no harvest of hatchery-origin UKTR spring Chinook Salmon (indicated as dashes in Table 6.14) between brood years 1995 – 2012. The highest recovery rate, 28 UKTR spring Chinook Salmon per 1,000 total all-stocks, occurred during April in the Fort Bragg management area between Horse Mountain and Point Arena; however, this fishery was held only in 2007. The area between the OR/CA Border to Humboldt South Jetty, California’s portion of the Klamath Management Zone (KMZ), during May represented the second highest commercial recovery rate (19 UKTR spring Chinook Salmon per 1,000 total all-stocks), but like Fort Bragg in April, this represents only one year of data (2013).

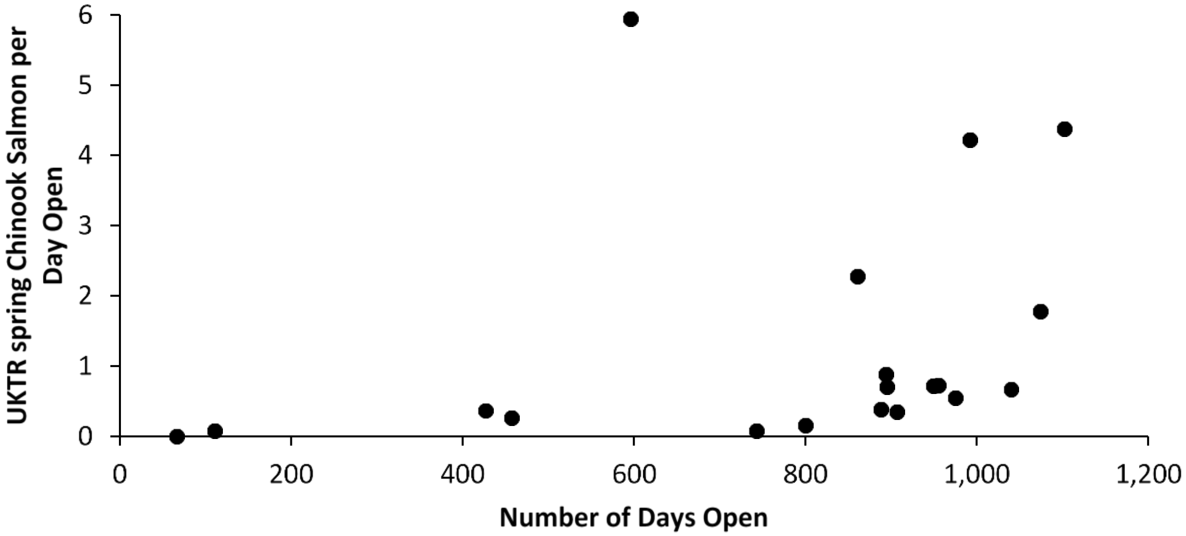

Figure 6.19. Commercial ocean harvest of UKTR spring Chinook Salmon per day open to fishing (all management areas south of Cape Falcon, Oregon, combined).

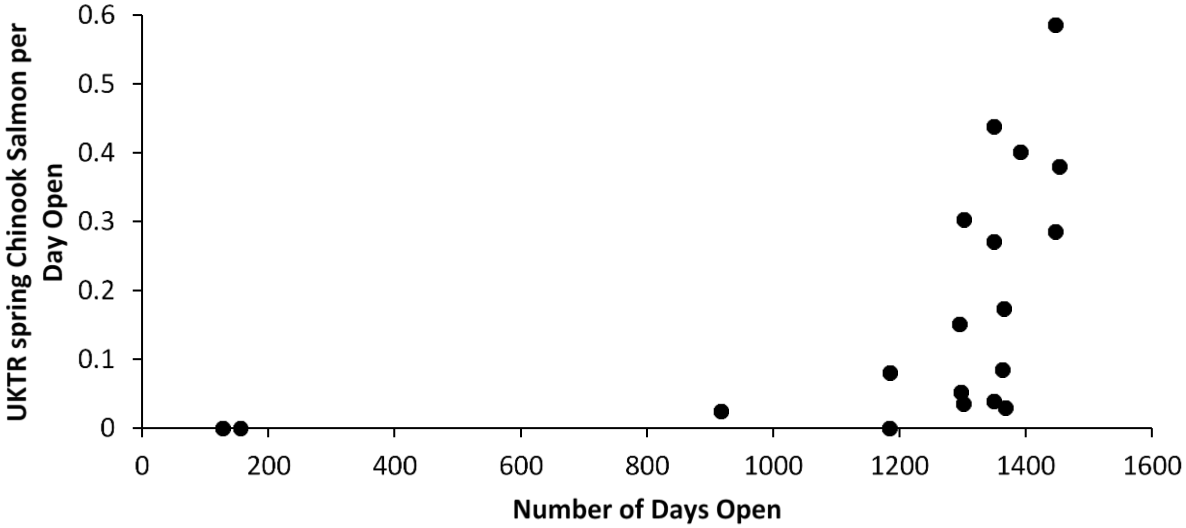

Figure 6.20. Recreational ocean harvest of UKTR spring Chinook Salmon per day open to fishing (all management areas south of Cape Falcon, Oregon, combined).

Ordinarily, the California KMZ commercial salmon fishery is open only during September, if at all. Note that ocean commercial fisheries south of Point Arena during April are discontinued per the SRWC Biological Opinion. Allowable Oregon state-water commercial fisheries during November and December are not shown because no UKTR spring Chinook Salmon were harvested there.

Table 6.18. Commercial ocean harvest of UKTR spring Chinook Salmon per 1,000 all-stocks by management area and month; brood years 1995 – 2012.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Cape Falcon-Florence S. Jetty	5	3	2	1	0.3	1	5	4
Florence S. Jetty-Humbug Mtn.	12	8	6	3	2	4	15	11
Humbug Mtn.-OR/CA Border	-	-	7	9	7	8	7	-
OR/CA Border-Horse Mtn.			19	6	9	4	5	
Horse Mtn.-Pt. Arena		28	10	2	3	4	6	
Pt. Arena-Pigeon Pt.		1	4	2	1	1	1	1
Pigeon Pt.-South		-	3	1	0.4	-	-	

Recreational ocean harvest of UKTR spring Chinook Salmon ranged from less than one fish per 1,000 total Chinook Salmon harvested up to 13 UKTR spring Chinook Salmon per 1,000 (Table 6.19), with highest recovery rates during May and October in the Florence South Jetty to Humbug Mountain (Coos Bay; 13 per 1,000) and May in the OR/CA Border to Horse Mountain area (CA-portion of the KMZ; 13 per 1,000). Like the commercial fishery, several open recreational areas/times did not harvest hatchery-origin UKTR spring Chinook Salmon (indicated by dashes) between brood years 1995 – 2012. Some allowable recreational ocean fisheries are not shown as no UKTR spring Chinook Salmon were harvested there (e.g., November outside of the KMZ). Note that ocean recreational fisheries south of Point Arena prior to April are no longer permitted per the Sacramento River Winter Chinook Biological Opinion.

Table 6.19. Recreational ocean harvest of UKTR spring Chinook Salmon per 1,000 of all stocks by management area; brood years 1995 – 2012.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Cape Falcon-Florence S. Jetty	-	-	-	4	1	0.3	2	2
Florence S. Jetty-Humbug Mtn.	-	-	13	2	3	3	6	13
Humbug Mtn.-OR/CA Border			6	9	3	1	6	-
OR/CA Border-Horse Mtn.			13	10	4	3	5	
Horse Mtn.-Pt. Arena	-	-	6	7	2	1	-	-
Pt. Arena-Pigeon Pt.	-	2	2	1	0.2	0.3	-	-
Pigeon Pt.-South	2	1	2	1	0.2	-	-	-

While the total harvest of UKTR spring Chinook Salmon is higher in the commercial fishery, the rate of harvest per total all-stocks is reasonably comparable across geographic locations and is also comparable to the recreational fishery (Tables 6.20 – 6.23). No single fishery, area, or time of year appeared to dominate ocean harvest of hatchery-origin UKTR spring Chinook Salmon.

However, the highest UKTR spring Chinook Salmon recovery rate areas may not represent the time-area-fishery with the highest total harvest, as harvest differs among years, months, geographic locations, and fishery type dependent on target-stock, ocean abundance, and fishing opportunity (i.e., days open to fishing in a given location and time of year). The Department evaluated potential ocean salmon fishery harvest of UKTR spring Chinook Salmon across a range of fishing seasons by calculating the average harvest of all-stocks by management area and month coupled with hatchery-origin UKTR spring Chinook Salmon ocean recovery rates (i.e., the number of UKTR spring Chinook Salmon harvested per 1,000 all-stocks). The Department urges caution when interpreting this information due to the inter-annual variability in total harvest rates and fishing opportunity (i.e., the number of days open to fishing).

In general, should future commercial ocean salmon fishing opportunity and total all-stock harvest be similar to the average of the previous twenty-one years the Department would expect that more UKTR spring Chinook Salmon could potentially be harvested in May between Horse Mountain and Pigeon Point (Table 6.21; Fort Bragg and San Francisco management areas) than at other times and areas. While the recovery rate of UKTR spring Chinook Salmon in the San Francisco area is less than half the recovery rate in Fort Bragg, the total harvest of all-stocks is over double, resulting in similar potential average harvest of UKTR spring Chinook Salmon. Likewise, if recreational harvest of all-stocks and fishing opportunity remains similar, UKTR spring Chinook Salmon harvest could potentially be highest during May and June in the California KMZ.

Table 6.20. Average commercial harvest in numbers of Chinook Salmon by management area and month, all stocks; harvest years 1997 – 2017.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Cape Falcon-Florence S. Jetty	7,319	5,275	14,647	12,771	7,455	14,384	10,716	6,998
Florence S. Jetty-Humbug Mtn.	7,479	7,490	10,195	10,739	5,663	16,017	8,455	3,406
Humbug Mtn.-OR/CA Border	25	47	1,240	1,036	1,090	931	739	446
OR/CA Border-Horse Mtn.			2,688	2,924	1,979	1,629	3,665	
Horse Mtn.-Pt. Arena		748	19,582	17,046	36,285	21,641	10,985	
Pt. Arena-Pigeon Pt.		3,266	40,130	40,012	45,560	16,089	10,590	1,642
Pigeon Pt.-South		5,947	29,859	16,832	12,498	1,130	373	

Table 6.21. Average[a] commercial harvest of hatchery-origin UKTR spring Chinook Salmon by management area and month; brood years 1995 – 2012.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Cape Falcon-Florence S. Jetty	35	18	24	12	2	14	50	30
Florence S. Jetty-Humbug Mtn.	90	57	63	32	11	71	126	36
Humbug Mtn.-OR/CA Border	0	0	8	9	8	8	5	
OR/CA Border-Horse Mtn.			51	19	17	7	17	
Horse Mtn.-Pt. Arena		21	193	26	121	80	66	
Pt. Arena-Pigeon Pt.		5	172	68	44	9	6	1
Pigeon Pt.-South		0	81	9	5	0	0	

[a] Average harvest of all stocks times the TRH UKTR spring Chinook Salmon recovery rate.

Table 6.22. Average recreational harvest in numbers of Chinook Salmon by management area and month from all-stocks; harvest years 1997 – 2017.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Cape Falcon-Florence S. Jetty	33	24	101	277	1,635	1,420	1,381	907
Florence S. Jetty-Humbug Mtn.	3	14	75	830	2,500	1,966	641	15
Humbug Mtn.-OR/CA Border			277	812	1,026	1,761	626	530
OR/CA Border-Horse Mtn.			1,965	3,821	3,368	3,816	1,095	
Horse Mtn.-Pt. Arena	238	461	1,243	3,162	5,211	2,401	315	23
Pt. Arena-Pigeon Pt.	1,282	3,938	7,068	9,442	18,936	9,260	4,706	1,990
Pigeon Pt.-South	4,577	10,215	3,251	4,521	4,747	744	203	44

Table 6.23. Average[a] recreational harvest of hatchery-origin UKTR spring Chinook Salmon by management area and month; brood years 1995 – 2012.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Cape Falcon-Florence S. Jetty	0	0	0	1	2	0	2	2
Florence S. Jetty-Humbug Mtn.	0	0	1	1	6	7	4	0
Humbug Mtn.-OR/CA Border			2	8	3	2	4	0
OR/CA Border-Horse Mtn.			25	40	12	10	6	
Horse Mtn.-Pt. Arena	0	0	8	22	10	3	0	0
Pt. Arena-Pigeon Pt.	0	9	11	8	3	2	0	0
Pigeon Pt.-South	8	8	8	3	1	0	0	0

[a] Average harvest of all-stocks times the TRH UKTR spring Chinook Salmon recovery rate.

In summary, based on ocean catch of TRH UKTR spring Chinook Salmon, overall ocean harvest of UKTR spring Chinook Salmon appears to be small and comprises a very small percentage of ocean harvest. Management measures are in place to both directly and indirectly protect UKTR spring Chinook Salmon through weak stock management (See Section 7.4.1).

6.11.4 Tribal In-River Harvest

Only UKTR fall Chinook Salmon (KRFC) are currently managed under the Pacific Fishery Management Council (PSMFC). The stock is allocated under a 50:50 sharing agreement. Because PFMC does not manage UKTR spring Chinook Salmon as a separate stock, the state and the tribes are each responsible for harvest management of spring Chinook Salmon in the absence of PSMFC allocation. In-river harvest, both recreational and tribal are governed by quotas determined by the PMFC that target in-river escapement objectives.

Salmon are a critically important cultural and nutritional resource for the Klamath River tribes. Prior to European colonization and later dam construction and habitat modification, salmon supported the traditional hunter-gatherer societies of native peoples in the Klamath basin. Hoopa and Yurok tribal fisheries are conducted on tribal lands.

The heaviest fishery on Yurok lands is currently in the estuary below the Highway 101 bridge, although there are fishers spread out all the way upstream to Trinity River confluence. The Hoopa fishery is spread out throughout the Hoopa Valley Tribe Reservation. There is also a Karuk tribal fishery. However, the Karuk Tribe does not currently provide harvest data to the Department for inclusion into the UKTR fall Chinook Salmon megatable. The impact of Karuk tribal fisheries on UKTR spring Chinook Salmon is likely small since their fishery is upstream of the Trinity River confluence and so does not contact Trinity basin UKTR spring Chinook Salmon (W. Sinnen, CDFW, Personal Communication, January 2020).

In 1986, the Hoopa Valley Tribe adopted the *Hoopa Tribal Fishing Ordinance* to allow the tribe to exercise jurisdictional control over fisheries on tribal lands. The ordinance contains elements that direct tribal control over who can fish, identification of authorized persons, type of gear, seasons, and other provisions. Under this ordinance, for the 1986 season, salmon fishing was allowed for all species of anadromous fish from 1 July through 24 December, 24 hours per day, 7 days per week, except for a period to collect abandoned or lost fishing gear. The Department is not aware of annual fishery management plans promulgated by the Hoopa Tribal Fisheries Department or Tribal Council to govern annual fishing restrictions or harvest.

The Yurok Tribe produces an annual harvest management plan primarily focused on UKTR fall Chinook Salmon. However, the Yurok Tribe also implements management to protect UKTR spring Chinook Salmon through closures and other tribal fishery management actions.

In cooperation with tribal fishery agencies, the Department maintains records of Hoopa and Yurok tribal harvest of UKTR spring Chinook Salmon. Figure 6.21 and Table 6.24 show the annual tribal harvest for the Hoopa and Yurok tribes from 1980-2017. Annual tribal harvest for both Hoopa and Yurok tribes has typically ranged from a few hundred to several thousands of UKTR spring Chinook Salmon. Yurok tribal harvest was much larger in 2001 and 2002, in the tens of thousands. Average harvest was 1,458 UKTR spring Chinook Salmon for the Hoopa Tribe, and 4,422 for the Yurok Tribe.

Table 6.24. Hoopa and Yurok tribal harvest of UKTR spring Chinook Salmon, 1980 – 2017.

Year	Hoopa Tribe	Yurok Tribe	All Tribal Harvest
1981	1,107	1,717	2,824
1982	725	2,440	3,165
1983	75	510	585
1984	380	247	627
1985	1,115	1,074	2,189
1986	2,022	692	2,714
1987	4,268	1,646	5,914
1988	2,811	2,918	5,729
1989	1,998	4,745	6,743
1990	889	1,413	2,302
1991	263	283	546
1992	346	396	742
1993	228	550	778
1994	255	501	756
1995	1,268	2,592	3,860
1996	1,188	5,905	7,093
1997	1,251	5,440	6,691
1998	471	2,338	2,809
1999	789	2,392	3,181
2000	1,897	3,207	5,104
2001	4,210	14,890	19,100
2002	3,232	12,266	15,498
2003	2,384	6,690	9,074
2004	2,006	3,610	5,616
2005	1,875	2,258	4,133
2006	1,690	2,718	4,408
2007	1,355	4,494	5,849
2008	1,404	2,029	3,433
2009	1,838	1,762	3,600
2010	1,744	3,279	5,023
2011	2,390	2,615	5,005
2012	2,668	3,622	6,290
2013	1,221	3,760	4,981
2014	1,818	3,161	4,979
2015	1,102	2,577	3,679

Year	Hoopa Tribe	Yurok Tribe	All Tribal Harvest
2016	693	1,001	1,694
2017	420	889	1,309
Averages	**1,497**	**3,044**	**4,541**
max	**4,268**	**14,890**	**19,100**
min	**75**	**247**	**546**

UKTR fall Chinook Salmon tribal net fishery harvest is shown in Table 6.25. Although highly variable over the monitoring period, average take is approximately 20% of the total UKTR fall Chinook Salmon returns. This rate of harvest is moderately large given the overall abundance of UKTR fall Chinook Salmon and the ESU as a whole.

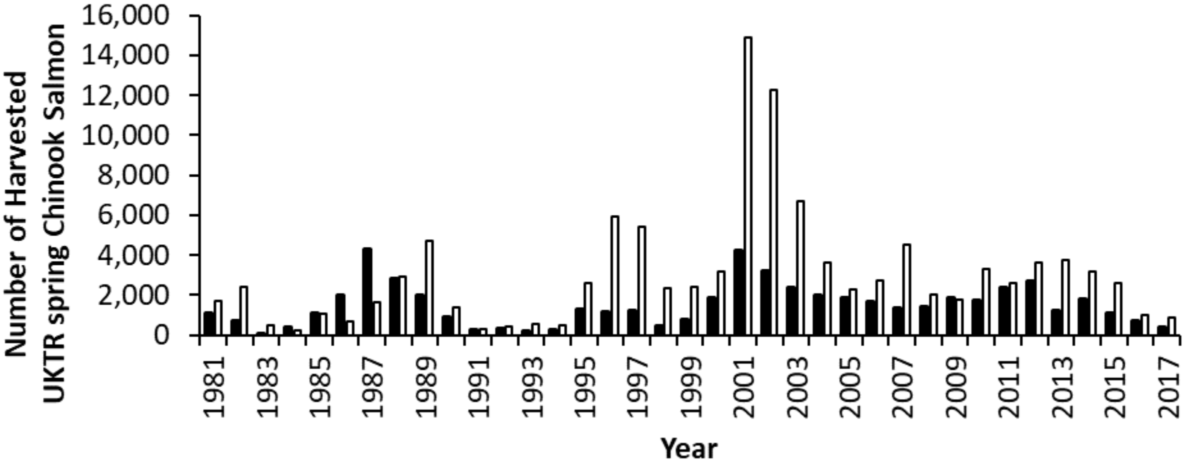

Figure 6.21. Tribal UKTR spring Chinook Salmon in-river harvest, 1981 – 2017. Black bars are Hoopa tribal harvest and white bars are Yurok tribal harvest.

Table 6.25. UKTR fall Chinook Salmon net harvest, 1978 – 2018.

Year	Grilse	Adults	Total	Rate
1978			20,000	0.173
1979			15,000	0.238
1980	987	12,013	13,000	0.158
1981	2,465	33,033	35,498	0.327
1982	1,799	14,482	16,281	0.154
1983	163	7,890	8,053	0.131
1984	455	18,670	19,125	0.344
1985	1,555	11,566	13,121	0.098

Year	Grilse	Adults	Total	Rate
1986	854	25,127	25,981	0.108
1987	415	53,096	53,511	0.235
1988	578	51,651	52,229	0.242
1989	191	45,565	45,756	0.343
1990	190	7,906	8,096	0.201
1991	62	10,198	10,260	0.298
1992	366	5,785	6,151	0.152
1993	175	9,636	9,811	0.151
1994	293	11,692	11,985	0.153
1995	557	15,557	16,114	0.066
1996	190	56,476	56,666	0.306
1997	35	12,087	12,122	0.132
1998	53	10,187	10,240	0.107
1999	271	14,660	14,931	0.212
2000	303	29,415	29,718	0.13
2001	399	38,645	39,044	0.197
2002	126	24,574	24,700	0.145
2003	44	30,034	30,078	0.154
2004	168	25,803	25,971	0.293
2005	70	8,016	8,086	0.12
2006	415	10,283	10,698	0.121
2007	21	27,573	27,594	0.206
2008	641	22,259	22,900	0.239
2009	178	28,387	28,565	0.254
2010	428	29,887	30,315	0.282
2011	1,322	26,353	27,675	0.148
2012	177	95,386	95,563	0.302
2013	259	63,036	63,295	0.353
2014	348	25,967	26,315	0.144
2015	496	28,048	28,544	0.34
2016	160	5,160	5,320	0.194
2017	266	1,880	2,146	0.04
2018	308	14,769	15,077	0.146
Avg	**456**	**24,686**	**24,769**	**0.198**

6.11.5 Non-Tribal In-River Harvest

Because there is no PSMFC allotment of UKTR spring Chinook Salmon, the state has sole responsibility for their management in the basin. The Fish and Game Commission is the only entity that promulgates regulations specific to UKTR spring Chinook Salmon. Generally, regulations have been conservative for UKTR spring Chinook Salmon, including closures and smaller bag and possession limits than for UKTR fall Chinook Salmon.

The Department maintains records of non-tribal sport harvest of UKTR spring Chinook Salmon in the Klamath and Trinity Rivers (Table 6.26 and Figure 6.22). Beginning in 2010, the Department implemented a dedicated creel survey focused on UKTR spring Chinook Salmon harvest in the lower Klamath River. Prior to 2010, harvest estimates only captured the end of UKTR spring Chinook Salmon harvest season in early August.

Most of the sport fishing for UKTR spring Chinook Salmon is in the lower 32.2 km (20 miles) of the Klamath River and in the Upper Trinity River, particularly at the Burnt Ranch and Greys Falls area, and the area from Junction City to Lewiston Dam. There are sportfishing closures above Weitchpec on the Klamath (Trinity Confluence) and the Lower Trinity River below the South Fork Trinity River. These closures were specifically put into place to protect wild UKTR spring Chinook Salmon.

Figure 6.22 shows that sport harvest has declined in relation to the peak harvest period in the mid-1980s; however, the cyclic pattern of harvest since that time shows about the same highs and lows at a lower average. Averages for the entire period show that sport harvest is largest in the Trinity River (1,007 spring Chinook Salmon annually) and lower in the Klamath River (468 spring Chinook Salmon annually). Recent harvest (since 2012) has declined; however, the pattern and amount of decline is similar to that seen in previous declines (e.g., 1989 – 92 and 2002 – 2009). The lowest numbers during the recent decline are marginally higher than those in the lowest point of previous decline periods. Although creel surveys prior to 2010 were limited, available data suggest that until about 2009 (and again in 2012), most of the sport harvest was in the Trinity River. Recent sport harvest has shifted to a larger proportion taken in the lower Klamath.

Sport harvest totals for UKTR fall Chinook Salmon (Table 6.27) show that in-river harvest has varied. The average harvest rate over the monitoring period is around 8%, which is moderate in relation to overall abundance of the fall component and the UKTR Chinook Salmon ESU as a whole.

Overall sport harvest of both UKTR spring and fall Chinook Salmon is moderate in comparison to overall ESU-level abundance in the Klamath basin. Relatively larger harvest of UKTR spring Chinook Salmon in the Trinity River is likely supportable due to the presence of larger numbers there and the presence of hatchery-origin UKTR spring Chinook Salmon from TRH. However, given the low abundance of UKTR spring Chinook Salmon in the Klamath River (Salmon River), even the relatively small numbers of spring ecotype fish harvested there deserve more scrutiny.

Table 6.26. Non-tribal in-river UKTR spring Chinook Salmon sport harvest in the Klamath and Trinity rivers, 1980 – 2017.

Year	Klamath Sport Harvest	Trinity Sport Harvest	Total Sport Harvest
1980		424	424
1981		2,156	2,156
1982		756	756
1983			
1984		414	414
1985		863	863
1986		4,171	4,171
1987		9,361	9,361
1988	148	8,840	8,988
1989	145	2,630	2,775
1990	17	845	862
1991	108	336	444
1992	17	298	315
1993		423	423
1994	96	454	550
1995	464		464
1996	670	1,513	2,183
1997	786	1,330	2,116
1998	412	1,680	2,092
1999	645	667	1,312
2000	161	1,807	1,968
2001	898	1,164	2,062
2002	812	1,871	2,683
2003	246	2,033	2,279
2004	33	889	922
2005	93	961	1,054
2006	158	17	175
2007	97	565	662
2008	248	306	554
2009	48	442	490
2010	749	463	1,212
2011	1,587	112	1,699

Year	Klamath Sport Harvest	Trinity Sport Harvest	Total Sport Harvest
2012	775	2,139	2,914
2013	1,362	243	1,605
2014	1,276	226	1,502
2015	533	190	723
2016	532	216	748
2017	452	104	556
2018	992	265	1,257
Average	**485**	**1,130**	**1,544**
max	**1,587**	**9,361**	**9,361**
min	**17**	**17**	**175**

Table 6.27. Non-tribal in-river UKTR fall Chinook Salmon sport harvest in the Klamath and Trinity rivers, 1978 – 2018.

Year	Grilse	Adults	Total	Rate
1978	2,082	1,694	3,776	0.033
1979	2,181	2,141	4,322	0.069
1980	5,891	4,496	10,387	0.126
1981	7,252	5,983	13,235	0.122
1982	12,484	8,339	20,823	0.196
1983	351	4,235	4,586	0.075
1984	952	3,340	4,292	0.077
1985	11,195	3,582	14,777	0.110
1986	9,408	21,027	30,435	0.127
1987	5,436	20,169	25,605	0.112
1988	5,411	22,203	27,614	0.128
1989	2,267	8,775	11,042	0.083
1990	2,100	3,553	5,653	0.140
1991	686	3,383	4,069	0.118
1992	4,120	1,002	5,122	0.127
1993	1,925	3,172	5,097	0.079
1994	2,556	1,832	4,388	0.056
1995	4,420	6,081	10,501	0.043
1996	2,312	12,766	15,078	0.081
1997	2,409	5,676	8,085	0.088
1998	1,108	7,710	8,818	0.093
1999	1,616	2,282	3,898	0.055

Year	Grilse	Adults	Total	Rate
2000	1,582	5,650	7,232	0.032
2001	1,500	12,134	13,634	0.069
2002	870	10,495	11,365	0.067
2003	814	9,680	10,494	0.054
2004	2,741	4,003	6,744	0.076
2005	1,030	1,985	3,015	0.045
2006	5,527	62	5,589	0.063
2007	369	6,312	6,681	0.050
2008	4,308	1,919	6,227	0.065
2009	2,214	5,651	7,865	0.070
2010	1,831	3,035	4,866	0.045
2011	9,981	4,147	14,128	0.076
2012	3,875	13,876	17,751	0.056
2013	2,260	19,800	22,060	0.123
2014	3,364	5,386	8,750	0.048
2015	1,605	7,842	9,447	0.113
2016	162	1,310	1,472	0.054
2017	42	71	113	0.002
2018	2,206	4,075	6,281	0.061
Average:	**3,279**	**6,607**	**9,886**	**0.081**

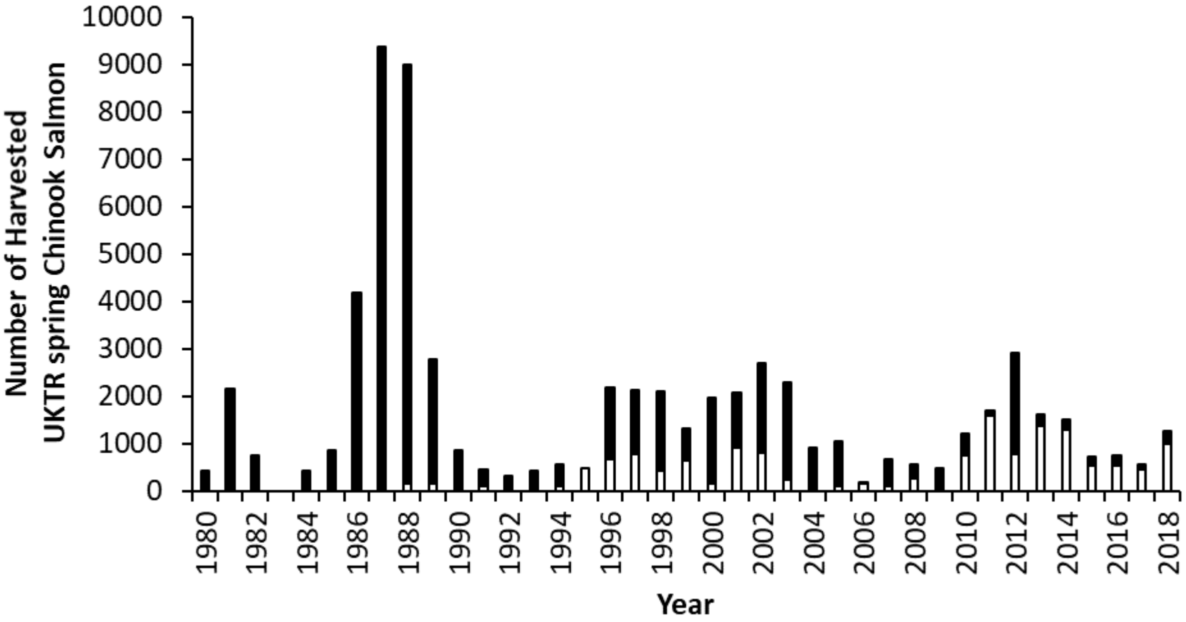

Figure 6.22. Number of UKTR spring Chinook Salmon harvested in non-tribal, in-river, sport fisheries. Black bars are Trinity River harvest and white bars are Klamath River harvest.

6.12 Timber Harvest

Timber harvest has been studied in the latter portion of the twentieth century regarding its effect on anadromous salmonids of the Pacific Northwest, including those inhabiting coastal watersheds in California (Burns 1972; Meehan 1991; Murphy 1995).

Legacy forestry practices are often cited as cause for declines in anadromous salmonid numbers and quality of habitat. In 1964, historic precipitation acting on clear-cut mountainsides led to catastrophic landslides that contributed millions of cubic yards of sediment to streams, destroying salmonid spawning and rearing habitat (Campbell and Moyle 1991). Overall, though, the UKTR Chinook Salmon ESU is not in decline and declines in the spring ecotype are primarily due to factors other than timber harvest.

6.13 Gravel Extraction

Sand, gravel, and crushed rock are the most economically important mineral resources in the region. There are many small aggregate production sites. Asbestos, chromium, clay, copper, diatomite, gold, graphite, and mercury are also mined in the Klamath basin.

Instream gravel mining typically occurs within lower gradient depositional portions of rivers near population centers where aggregate is often processed into sand, gravel, crushed rock (i.e., road base) and sorted gravel. Gravel mining and gravel use often involves construction and operation of on-site asphalt batch plants. River run gravel is typically extracted during the summer and fall months during summer low flows. Extraction can be in the form of bar skims, in-channel trenches, or upland (high flood plain) terrace pits and trenches. In some locations, in-channel wetted features such as alcoves are desirable and prescribed for the enhancement of off-channel salmonid habitat or to improve passage into tributaries. Gravel mining in general occurs outside of the wetted channel of larger tributaries and rivers. Exceptions occur where summer bridges are installed to access river bars for extraction. However, summer bridges are designed to avoid direct impact or take of salmonids or other special status species.

In locations where instream gravel mining occurs (e.g., Hoopa Valley), both UKTR spring and fall Chinook Salmon are likely transitory and are unlikely to be directly harmed due to existing regulatory provisions provided by local, state, and federal laws. Some juvenile UKTR spring Chinook Salmon migrate downstream beginning in October, but most remain in the headwaters until spring (Moyle et al. 2008), and therefore have a low likelihood of direct impact or take from gravel extraction methods described above.

6.14 Legacy Mining Impacts

Declines in salmonid populations in the region likely began around the time of the California gold rush, about 1850. Hydraulic mining using pressurized water was commonly used to wash away entire hillsides adjacent to waterways. This caused extreme sediment input and movement that would have strongly affected both adult and juvenile salmonids as well as other aquatic species. Residual effect of this large-scale historical disturbance persists to the present (see Section 6.2).

6.15 Water Diversion

Diversion dam construction, water diversions, and other anthropogenic factors resulted in precipitous declines of UKTR spring Chinook Salmon in the 19th century (Snyder 1931). The large UKTR spring Chinook Salmon run in the Shasta River is thought to have all but disappeared with the construction of Dwinnell Dam in 1926 (Moyle et al. 1995). The dam continues to divert nearly one third of the flow from the Shasta River and block all fish passage (Lestelle 2012). In the mid to late 20th century, UKTR spring Chinook Salmon populations further declined as a result of hydropower dam construction projects including the Trinity and Iron Gate dams. In 1964, historic precipitation led to catastrophic landslides of clear-cut mountainsides contributing millions of cubic yards of sediment in streams and destroying spawning and rearing habitat (Campbell and Moyle 1991). UKTR spring Chinook Salmon had largely been eliminated from much of their former habitats by the 1980’s as the cold, clear water and deep pools that they require were either absent or inaccessible (NMFS 2018).

Water diversions including Young’s Dam, coupled with ground water pumping, is known to dewater Chinook Salmon habitat in the Scott River. Lewiston Dam on the Trinity River diverted most of the Trinity River water to the Sacramento basin and practically eliminated instream flows in the Trinity River prior to implementation of the Trinity River Restoration Plan. In addition, Lewiston Dam blocks Chinook Salmon access to the Trinity headwaters. It is generally recognized that over a century of dam construction and operation, and water diversions from both the Klamath and Trinity Rivers and tributaries, is a leading cause of declines in UKTR spring and fall Chinook Salmon and other salmonids.

7. Influence of Existing Management

7.1 Klamath River Dam Removal

Four hydroelectric dams located on the Klamath River (J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate dams) are slated for removal in 2022 if permits are received on schedule (Figure 7.1). This extensive dam removal project is intended to achieve free-flowing conditions and volitional fish passage to upper portions of the Klamath River basin. Prior to dam building on the Klamath River, UKTR spring Chinook Salmon likely accounted for most of the Upper Klamath basin's natural salmon production (Huntington 2006).

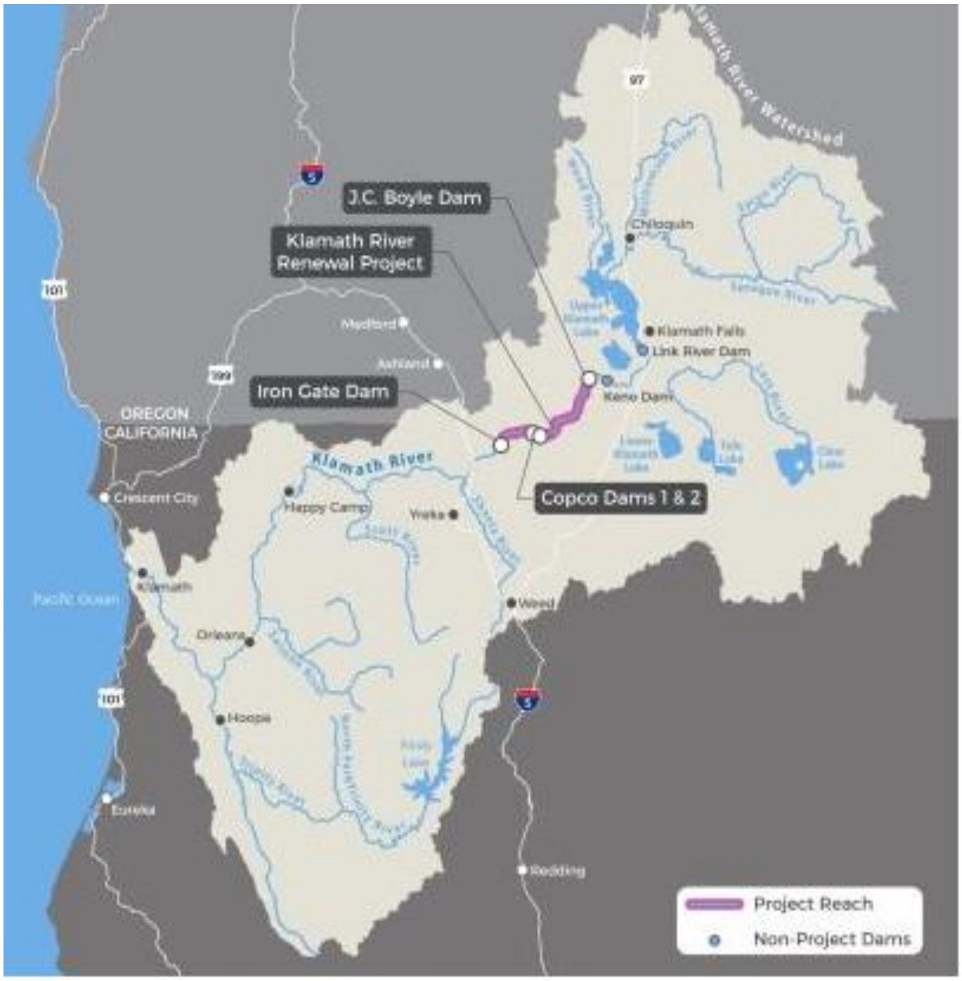

Figure 7.1. Klamath River watershed and development locations.

UKTR spring Chinook Salmon were known to spawn in the tributaries of the Upper Klamath basin (Moyle 2002, Hamilton et al. 2005, Hamilton et al. 2016) with large numbers of UKTR spring Chinook Salmon spawning in the basin upstream of Klamath Lake in the Williamson, Sprague, and Wood rivers (Snyder 1931). The runs in the Upper Klamath basin are thought to have been in substantial decline by the early 1900s and were eliminated by the completion of Copco No. 1 Dam in 1917 (Snyder 1931).

The decline of the Klamath River UKTR spring Chinook Salmon prior to Copco No. 1 Dam has been attributed to dams, overfishing, irrigation, and commercial hydraulic mining (Coots 1962; Snyder 1931). Large-scale mining operations occurred primarily in the late 1800's, and along with overfishing, resulted in diminished UKTR spring Chinook Salmon representation in the basin prior to large dam construction in the early 1900's. Dams have eliminated access to much of the historical UKTR spring Chinook Salmon spawning and rearing habitat and are at least partly responsible for the extirpation of at least seven spring population components from the Klamath-Trinity River system (Myers et al. 1998). For example, the construction of Dwinnell Dam on the Shasta River in 1926 was soon followed by the disappearance of the UKTR spring Chinook Salmon run in that tributary (Moyle et al. 1995).

Currently, UKTR spring Chinook Salmon in the Klamath basin are found mostly in the Salmon and Trinity rivers and in the mainstem Klamath River downstream from these tributaries during migratory periods, although a few fish are occasionally observed in other areas (Stillwater Sciences 2009 and this report). Based on data from 2005-2014 (CDFW 2015), the Salmon River contributions to the overall escapement of UKTR spring Chinook Salmon ranged from 1-12% of the total escapement, and from 1-20% of the natural escapement. To date, no UKTR spring Chinook Salmon spawning has been observed in the mainstem Klamath River (Shaw et al. 1997).

In the short term, dam removal activities will alter suspended sediment concentrations, bedload sediment transport and bedload deposition. Since UKTR spring Chinook Salmon are primarily distributed in the Klamath River downstream of the Salmon River their exposure to temporarily elevated concentrations of suspended sediment that would occur in the mainstem Klamath River due to dam removal would be limited. No impact from suspended sediment is anticipated for all UKTR spring Chinook Salmon spawning and rearing (SWRCB 2018). Suspended sediment is anticipated to have sublethal effects on adult migration, primarily for those adults returning to the Salmon River (around 5% of all spring migrants). All out-migrating Salmon River UKTR spring Chinook Salmon smolts enter the Klamath River far enough downstream from the dam removal project that suspended sediment concentrations are predicted to be much lower than further upstream. Under existing conditions, suspended sediment concentrations can be naturally quite high from tributary contributions of suspended sediment; therefore, sublethal effects on outmigrants are predicted to be similar to existing conditions (SWRCB 2018). Based on no predicted substantial short-term decrease in UKTR spring Chinook Salmon abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to UKTR spring Chinook Salmon in the short term due to the Klamath River dam removal project (SWRCB 2018).

In the long term, removal of the Klamath River dams will increase habitat availability, restore a more natural temperature regime, improve water quality, and reduce the likelihood of fish disease, all of which would be beneficial for UKTR spring Chinook Salmon. Dam removal would restore connectivity to hundreds of kilometers of potentially usable habitat in the Upper Klamath basin, including additional habitat within the reach where the dams are currently situated. Access to additional habitat will provide a long-term benefit to UKTR spring Chinook Salmon (SWRCB 2018). The expansion of habitat-choice opportunities would allow increased expression of life-history variation and the restoration of additional populations of UKTR spring Chinook Salmon with the effect of strengthening resiliency of Chinook Salmon in the Klamath basin, particularly because passage upstream of Iron Gate Dam would provide access to groundwater-fed thermal refugia during summer and fall, as well as providing slightly warmer winter water temperatures that are conducive to growth (Hamilton et al. 2011). By providing an unimpeded migration corridor, the dam removal project will provide the greatest possible fish-passage benefit, resulting in improved survival and reproductive success (Buchanan et al. 2011). As mentioned above, dam removal is predicted to result in warmer water earlier in the spring and early summer and cooler water earlier in the late summer and fall, with diurnal variation more in sync with historical migration and spawning periods in the mainstem upstream of the confluence with the Salmon River (Hamilton et al. 2011). These changes will result in more favorable water temperatures for UKTR spring Chinook Salmon in the mainstem, supporting fish that recolonize habitat upstream of the Salmon River.

Because of their widespread distribution and abundance in the Klamath basin, UKTR fall Chinook Salmon are likely to rapidly colonize suitable areas above the current dam sites when dams are removed.

Although their distribution and abundance in the Klamath River is limited, it is anticipated that dam removal will provide opportunities for the UKTR spring Chinook Salmon to increase in abundance and productivity, improve spatial structure, and create conditions conducive to maximizing and maintain genetic diversity. Implementation of the Klamath Dam Removal Project is predicted to be beneficial for UKTR spring Chinook Salmon in the long term (SWRCB 2018).

7.2 Salmonid Reintroduction Plans

In 1966, the Oregon Department of Fish and Wildlife (ODFW) initiated a study of the feasibility of reintroducing salmonids above barriers in the Klamath drainage (Fortune et al. 1966). As a result of that report, ODFW expressed support for reintroduction when and if above barrier passage became feasible.

The original FERC license for the Klamath Hydropower Project was granted in 1956 and expired in 2006. As a result of an administrative court ruling, relicensing required building and operating fishways to allow anadromous fish above dams. Because relicensing would be contingent upon development of upstream passage, ODFW developed *A Plan for the Reintroduction of*

Anadromous Fish in the Upper Klamath basin (ODFW 2008). This reintroduction plan was added as an amendment to ODFW's Klamath River basin Fish Management Plan. The reintroduction plan proposes two phases 1) development of an implementation plan to guide reintroduction and monitoring, and 2) a conservation plan to establish desired conservation status goals (e.g., escapement goals) for reintroduced populations.

In 2019, ODFW circulated a draft of the phase 1 reintroduction implementation plan for the restored river subsequent to removal of four dams (ODFW & Klamath Tribes 2019). The plan includes proposals for passive reintroduction of steelhead, Coho Salmon, and fall Chinook Salmon. Because UKTR spring Chinook Salmon are present in the Klamath at such small numbers (see *Section 4 Status and Trend*), natural passive reintroduction was judged unlikely to produce results in the desired time. Therefore, the plan proposes active reintroduction of spring Chinook Salmon to the basin. The original plan identifies Rogue River spring Chinook Salmon as the best source population; however, the actual population to be used has not yet been chosen, and other possibilities for a reintroduction source exist, including introducing spring alleles from Trinity River spring Chinook Salmon to Klamath River fall Chinook Salmon in an active conservation hatchery program. No decisions have been made at the time of this report.

The Klamath, Karuk, and Yurok tribes also produced a plan for upper river reintroductions (Huntington et al. 2006). Both reintroduction plans include recommendations for the method of reintroduction (passive, active, or some combination), stock selection, disease issues and management, and competition, restoration and monitoring priorities, and natural resource management strategies with emphasis on water and key species.

7.3 Forestry Activities and Timber Harvest

Currently, many agencies are taking actions to understand the direct and indirect effects of forestry activities on anadromous salmonids, more effectively implement current forest practice rules, and reduce impacts to potential or occupied anadromous habitat. In addition, efforts are underway to restore degraded anadromous habitat, estimate the status of anadromous salmonids in harvested watersheds, and increase anadromous salmonid populations. Along with the California Department of Fish and Wildlife, state agencies addressing timber harvest issues include the California Department of Forestry and Fire Protection (CalFire), California State Board of Forestry and Fire Protection (BOF), the California Regional Water Quality Control boards (RWQCB), and the California Geological Survey (CGSO). The two federal agencies primarily involved in timber harvest and anadromous salmonid issues are the NMFS and the USFS (CDFG 2002).

To further protect listed anadromous salmonids and their habitats, the Anadromous Salmonid Protection (ASP) rules were approved by the State Board of Forestry and Fire Protection (BOF) during their September 2009 meeting held in Sacramento, California. The rules were recently revised under the “Class II-L Identification and Protection Amendments, 2013” rule package approved by the BOF in October 2013.

As explained in the Final Statement of Reasons (FSOR) adopted by the BOF, the ASP rules are intended to protect, maintain, and improve riparian habitats for state and federally listed anadromous salmonid species. These rules are permanent regulations and replace the interim Threatened or Impaired Watershed Rules (T/I Rules) which were originally adopted in July 2000 and readopted six times.

The BOF’s primary objectives in adopting the ASP rules were: (1) to ensure rule adequacy in protecting listed anadromous salmonid species and their habitat, (2) to further opportunities for restoring the species’ habitat, (3) to ensure the rules are based on credible science, and (4) to meet Public Resources Code (PRC) Section 4553 for review and periodic revisions to FPRs. The main goals of the BOF for the rule revisions included having an update based on science, providing a high level of protection for listed species, having rules that contribute to anadromous salmonid habitat restoration, having consistency with partner agency mandates, and promoting landowner equity, flexibility and relief opportunities.

7.4 Commercial and Recreational Fishing

UKTR spring Chinook Salmon are classified as a non-target species by the PFMC (2016). However, both natural- and hatchery-origin UKTR spring Chinook Salmon population components provide minor contribution to ocean fisheries from Cape Falcon, Oregon, to Point Sur, California.

Weak Klamath River salmon stocks resulted in the closure of commercial salmon fishing in 2006 in the Klamath Management Zone on the California coast, and severely curtailed the commercial fishing season along the Oregon coast (USDI et al. 2012). The large spawning salmon fish kill in the Klamath River between 20 – 27 September 2002, may have affected salmon abundance in following years[14]. The federal government declared that year to be a fishery disaster and released $60 million in relief funds to help compensate losses to commercial fishermen and fishing related businesses in Oregon and California (Upton 2011). More recently, as of March 2017, the expected adult return of Klamath fall Chinook Salmon is forecast to be the lowest on record.

In inland waters, there are sportfishing closures above Weitchpec on the Klamath River (Trinity confluence) and on the Lower Trinity River below the South Fork Trinity River. These closures

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[14] However, spawning escapement in 2002 did not go below the established conservation floor and similar reduced abundance was observed in other cohorts that did not experience the fish kill.

were specifically put into place to protect natural-origin UKTR spring Chinook Salmon (W. Sinnen, CDFW, Personal Communication, January 2020)[15].

7.4.1 Ocean Fishery Management

Ocean salmon fisheries are intrinsically based on mixed stocks, meaning that several different ESUs or stocks are combined in the fishery and the origin of any individual harvested cannot be determined at the time of harvest. In mixed-stock fisheries, fishing is not focused on any one stock; however, fishing opportunity is designed to target relatively stronger stocks while protecting lower abundance stocks (i.e., “weak-stock management”). The most constraining stocks to ocean salmon fisheries can vary each year, however, exploitation rates and other harvest controls for ESA-listed Chinook are generally factors. When their abundance is low, UKTR fall Chinook Salmon (KRFC) (and/or Sacramento River fall Chinook Salmon) may also constrain fisheries.

For management planning of ocean fisheries, relatively data-rich Klamath River fall Chinook Salmon (KRFC) are used as the indicator-stock for all Klamath-Trinity basin Chinook Salmon stocks (including the spring ecotype component), as well as several southern Oregon and northern California stocks (e.g., Rogue and Smith rivers) (PFMC 2016, Table 7.1), and as a proxy for data-poor ESA-listed California coastal Chinook Salmon. Fisheries management is conducted at the stock complex level, assuming protections applied to Klamath River fall Chinook Salmon KRFC will similarly protect the other stocks within the complex. UKTR spring Chinook Salmon do not currently have stock-specific management measures, and the effectiveness of existing Klamath River fall Chinook Salmon (KRFC) management objectives to similarly protect them has not been quantitatively evaluated.

Table 7.1. Pacific Fishery Management Council ocean salmon fishery management areas.

Code	City	Location
NORS	Tillamook	Cape Falcon to Florence South Jetty, OR
NORS	Newport	
COS	Coos Bay	Florence S. Jetty to Humbug Mountain, OR
KMZO	Brookings	Humbug Mountain, OR, to OR/CA Border
KMZC	Crescent City	OR/CA Border to Big Lagoon, CA
KMZC	Eureka	Big Lagoon to Horse Mountain, CA (Humboldt S. Jetty for commercial fishery)
FTB	Fort Bragg	Horse Mountain to Point Arena, CA
SNF	San Francisco	Point Arena to Pigeon Point, CA
MON	Monterey	South of Pigeon Point, CA

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[15] These closures were in place for many years prior to the Fish and Game Code Section 2084 take allowance put in place during CESA candidacy.

The Pacific Coast Salmon FMP (PFMC 2016), as adopted by the PFMC, details how salmon are to be managed in federal ocean waters consistent with the Magnuson-Stevens Fishery Conservation and Management Act. Key elements of the plan include stock-specific conservation objectives and harvest control rules aimed at limiting harvest to achieve escapement targets. In addition to the Salmon FMP, the Council must also comply with consultation standards that establish harvest rate caps, maximum allowable impact rates, and specific time and area closures for ESA-listed salmon stocks. Together, the Salmon FMP and ESA consultation standards provide a management framework for constructing ocean salmon seasons on an annual basis. This framework is used by the PFMC to develop annual management recommendations that establish escapement objectives, harvest objectives, season dates, harvest quotas, minimum size lengths, and possession and landing restrictions. The NMFS implements the Council's recommendations by setting annual federal salmon fishing regulations. State management of stocks covered by the federal Salmon FMP must remain consistent with FMP conservation objectives, harvest rate caps, and allocation requirements.

One of the challenges in managing mixed stock ocean salmon fisheries is determining appropriate harvest levels for abundant stocks in the presence of less abundant stocks. Salmon stocks that are separated spatially and temporally in their natal rivers migrate to the ocean and intermingle along the coast. These stocks are visually indistinguishable at the time of harvest and as a result, "weak" stocks, such as state and federally listed ESUs, are often incidentally harvested along with more fish from more abundant healthy populations. Available CWT data of hatchery-origin stocks allow fisheries managers to make stock-specific ocean abundance forecasts and evaluate specific time and area fishery impacts. Using the best available science, fisheries managers aim to construct ocean salmon seasons that target abundant stocks, while limiting fishery impacts on stocks of special concern.

7.4.2 Sacramento River Fall Chinook and Klamath River Fall Chinook FMP Harvest Control Rules and Conservation Objectives

Sacramento River (SR) fall Chinook Salmon and UKTR fall Chinook Salmon (KRFC) are typically the most abundant stocks in California's ocean salmon fisheries and make up most of the ocean harvest. Due to their relative abundance, these two stocks are often the targets in California's ocean fisheries and therefore play an important role in the annual fisheries planning process. Management of these stocks is guided by FMP harvest control rules that limit harvest to appropriate levels based on anticipated abundance in order to achieve escapement targets (Figures 7.2, 7.3, 7.4).

SR fall Chinook Salmon and UKTR fall Chinook Salmon (KRFC) harvest control rules operate by setting allowable fishery exploitation rates based on potential spawning fish abundance forecasts absent fishing. Stock-specific biological reference points frame the curve of the harvest control rule and serve as triggers for management actions. Once the number of potential spawning fish is determined, the point of intersection at the curve of the line will determine the maximum allowable fishery exploitation rate expected to achieve the targeted level of spawning fish escapement in a given year. SR fall Chinook Salmon and UKTR fall Chinook Salmon (KRFC) are particularly important in the annual fisheries planning process because these two stocks typically make up the bulk of ocean harvest. When populations of these two target stocks decline, harvest control rules limit fishing by setting caps on fishery exploitation rates and therefore limiting the amount of harvest allowed for each stock.

Depending on the abundance forecast, the harvest control rule will take effect in one of three ways: 1) At higher spawning escapement forecast levels, the harvest control rule establishes a maximum exploitation rate that fisheries may not exceed. 2) At intermediate spawning escapement forecast levels, the harvest control rule establishes an exploitation rate intended to result in producing exactly the number of spawning fish specified in the conservation objective. 3) At lower spawning escapement forecast levels, fishing is still allowed but at much reduced exploitation rates, with the expectation that the conservation objective will not be met (*de minimis* fishing).

The UKTR fall Chinook Salmon (KRFC) harvest control rule with calculated stock-specific biological reference points is displayed in Figure 7.2. “Potential spawner abundance” absent fishing is defined in terms of natural area adult escapement due to availability of age-specific escapement data of natural-origin stocks, which allows for direct abundance forecasting methods. The FMP defined conservation objective for UKTR fall Chinook Salmon (KRFC) is set at 40,700 natural area adult spawning fish, which is the annual spawning adult escapement level determined to be optimum for producing the maximum sustainable yield (S_{MSY}) over the long-term. When the number of forecasted spawning fish, pre-fishery, ranges between 54,300 and 127,200 natural-area adults, the harvest control rule yields an exploitation rate that will produce, in expectation, the number of spawning fish defined in the FMP conservation objective (S_{MSY} or 40,700 natural area adults). Forecasted abundance of spawning fish above this range yields the maximum allowable exploitation rate of 68% while values below this range yield exploitation rates that require *de minimis* levels of fishing.

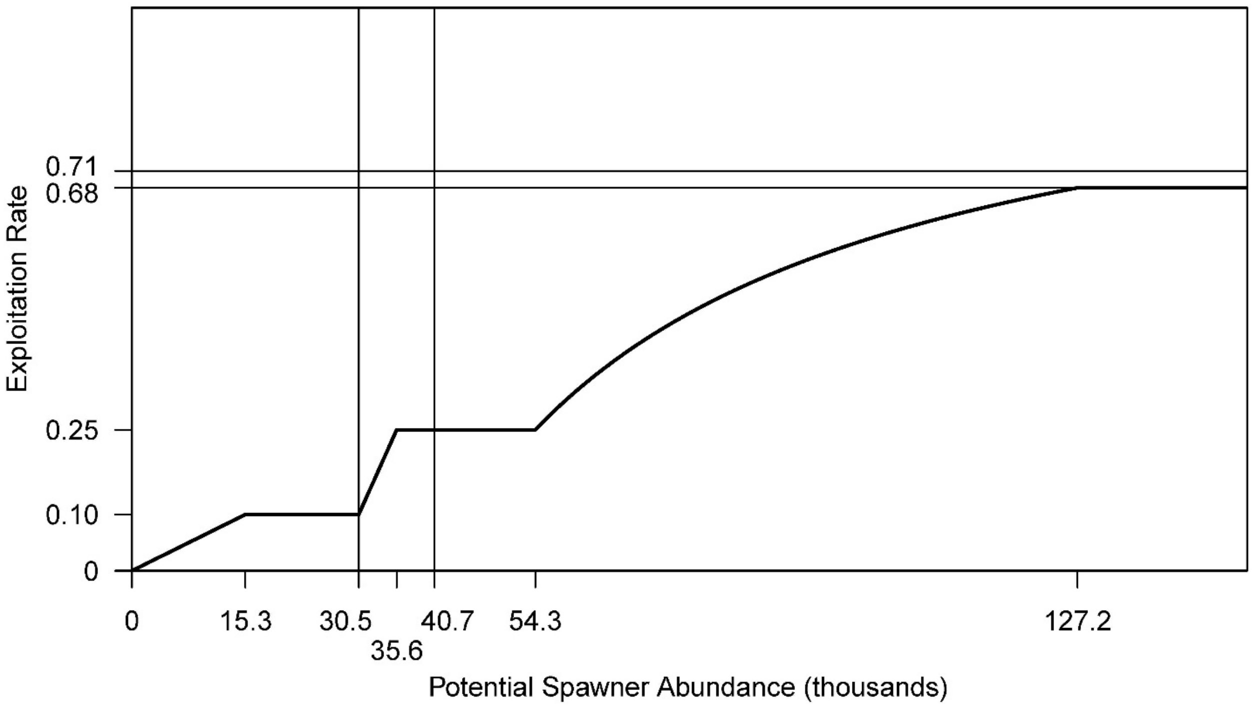

Figure 7.2. The Klamath River fall Chinook Salmon (KRFC) control rule. Potential Spawner Abundance is the predicted number of natural area adults returning to spawn, in the absence of fisheries.

The Sacramento River fall-run Chinook Salmon harvest control rule with calculated stock-specific biological reference points is displayed in Figure 7.3. The absence of age-specific escapement data for natural-origin spawning adults precludes direct abundance forecasting methods like those used for UKTR fall Chinook Salmon (KRFC), so an estimate for abundance known as the Sacramento Index (SI) is used to estimate potential spawning fish abundance. The SI is the sum of adult Sacramento River fall-run Chinook Salmon ocean harvest, river harvest, and hatchery and natural area spawning escapement. The annual SI forecast is generated using a model that relates jack escapement to SI abundance for past years to produce an estimate of hatchery and natural area adult spawning fish in the absence of fisheries. The FMP defined conservation objective for Sacramento River fall-run Chinook Salmon is 122,000 – 180,000 combined hatchery and natural area adult spawning fish, which is the range of escapement determined to be optimum for producing the maximum sustainable yield for the Central Valley fall Chinook stock complex (S_{MSY}). When the SI forecast ranges between 162,700 and 406,700 pre-fishery natural-area and hatchery adults, the harvest control rule yields an exploitation rate that will produce, in expectation, the minimum number of spawning fish defined in the FMP conservation objective (S_{MSY} or 122,000 hatchery and natural area spawning fish). An SI forecast above this range yields the maximum allowable exploitation rate of 70%, while values below this range yields exploitation rates that allow only *de minimis* levels of fishing.

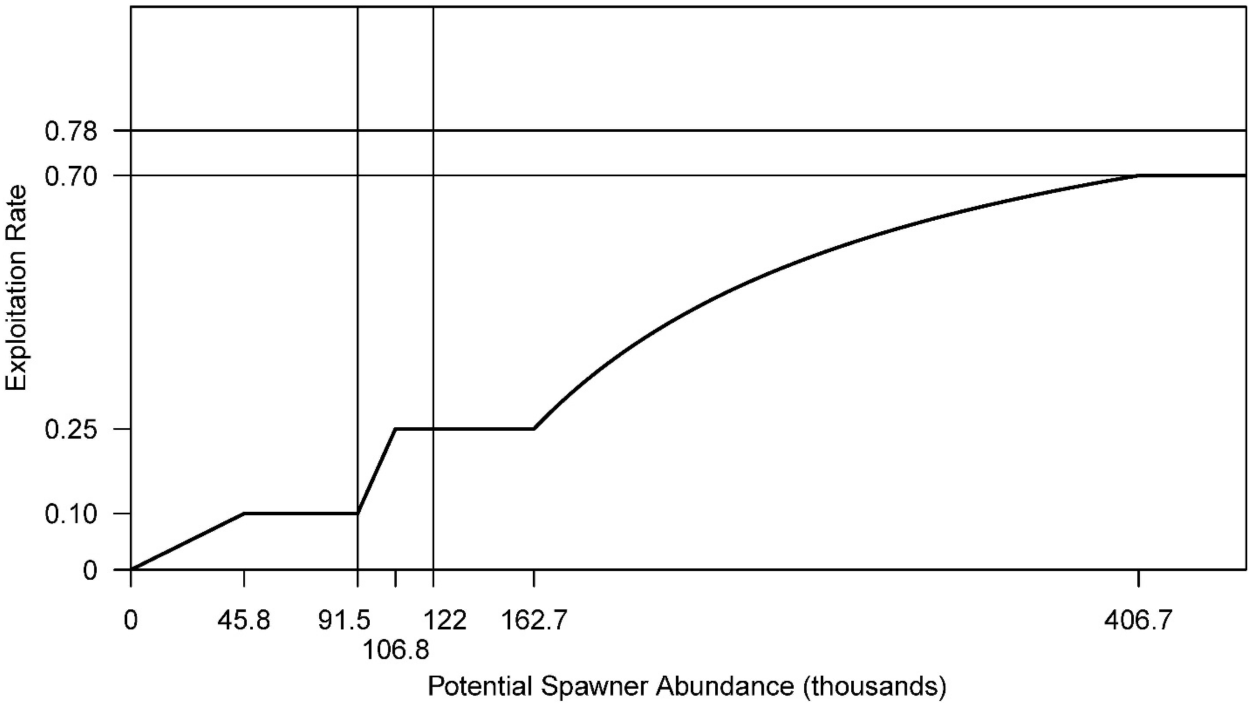

Figure 7.3. Sacramento River fall Chinook Salmon control rule. Potential Spawner Abundance is the predicted number of hatchery and natural area adults returning to spawn, which is equivalent to the Sacramento Index (SI).

7.4.3 Fishery Status Determination Criteria

The PFMC’s Salmon FMP outlines specific criteria for determining whether a salmon stock has been subject to overfishing, is approaching an overfished condition, or is overfished. A stock is considered to have been subject to overfishing when the postseason estimate of the fishing mortality rate exceeds the maximum fishing mortality threshold in any single year. A stock is considered to be approaching an overfished condition when the geometric mean of the two most recent postseason escapement estimates, and the current preseason escapement forecast is below the minimum stock size threshold (MSST). An overfished status determination is made when the geometric mean of the three most recent postseason escapement estimates is below the MSST. When a stock is declared overfished, the PFMC is required to direct the development a rebuilding plan which outlines contributing factors to the stock’s decline, evaluates management tools, and recommends actions to achieve a rebuilt status of the stock.

7.4.4 Sacramento River winter Chinook ESA Consultation Standard

ESA- and CESA-listed endangered Sacramento River (SR) winter Chinook Salmon are harvested incidentally in ocean fisheries, primarily in the San Francisco and Monterey management areas south of Point Arena. A two-part consultation standard is used as part of the annual management process to limit fishery impacts to this stock. The SR winter Chinook Salmon ESA consultation standard plays an important role in the annual fisheries planning process, as it often restricts fishing opportunity south of Point Arena, particularly in the sport fishery.

The first component of the SR winter Chinook Salmon consultation standard consists of specific fishery closures and size limit provisions in times and areas where SR winter Chinook Salmon are most likely to be encountered. Recreational fisheries in the San Francisco management area, located between Point Arena and Pigeon Point, shall open no earlier than the first Saturday in April and close no later than the second Sunday in November. Recreational fisheries in the Monterey management area, located between Pigeon Point and the U.S./Mexico Border, shall open no earlier than the first Saturday in April and close no later than the first Sunday in October. The minimum size limit must be at least 20 inches total length. The commercial salmon fishery between Point Arena and the U.S. – Mexico border shall open no earlier than 1 May and close no later than 30 September, with the exception of an October fishery conducted Monday through Friday between Point Reyes and Point San Pedro, which shall end no later than 15 October. The minimum size limit must be at least 26 inches total length.

The second component of the SR winter Chinook Salmon consultation standard is a control rule that specifies the maximum allowable impact rate based on a forecast of the age-3 escapement absent fishing (Figure 7.5). When the age-3 escapement absent fishing is forecasted to be 3,000 or more, the maximum forecast age-3 impact rate is 0.20. Between age-3 escapement absent fishing levels of 3,000 – 500, the maximum forecast age-3 impact rate decreases linearly from 0.20 – 0.10. At age-3 escapement absent fishing levels less than 500, the maximum forecast age-3 impact rate decreases linearly from 0.10 – zero.

7.4.5 California Coastal Chinook Salmon ESA Consultation Standard

The California coastal Chinook Salmon ESU is listed as threatened under the ESA and comprises all Chinook Salmon populations spawning in coastal rivers between Redwood Creek south to the Russian River. The lack of ocean harvest and spawning escapement data for this natural-origin stock prohibited the development of an abundance-based management strategy and necessitated the use of the fall Chinook Salmon (KRFC) proxy. The NMFS ESA consultation standard for California coastal Chinook Salmon restricts the KRFC age-4 ocean harvest rate to no more than 16.0%. By setting an ocean harvest rate cap on age-4 KRFC, this consultation standard serves to protect California coastal Chinook Salmon by limiting harvest and fishery impacts to times and areas where encounters with this stock are most likely to occur. This consultation standard is often a constraining factor in the annual fisheries planning process and results in reduced harvest and fishing opportunity in the Fort Bragg management area and the Klamath Management Zone.

7.4.6 Existing Regulatory Protection in Relation to Ocean Distribution

Ocean distribution based on analysis of CWT recoveries in ocean fisheries suggest that ocean distribution of UKTR spring and fall Chinook Salmon are similar (see Section 2.4). UKTR spring Chinook Salmon may extend to more northern catch areas and ocean presence is seasonal due to different migration timing. Because geographic distribution of the spring and fall ecotypes overlaps over much of the California and Oregon Coast, and because the harvest index of TRH produced UKTR spring Chinook Salmon is lower than UKTR fall Chinook Salmon (KRFC) in most areas, it is reasonable to infer that the UKTR fall Chinook Salmon (KRFC) harvest control rule and the California coastal Chinook Salmon ESU harvest rate proxy similarly protects UKTR spring Chinook Salmon overall. However, time-area combinations where the TRH UKTR spring Chinook Salmon harvest index exceeds the UKTR fall Chinook Salmon (KRFC) harvest index may warrant further scrutiny.

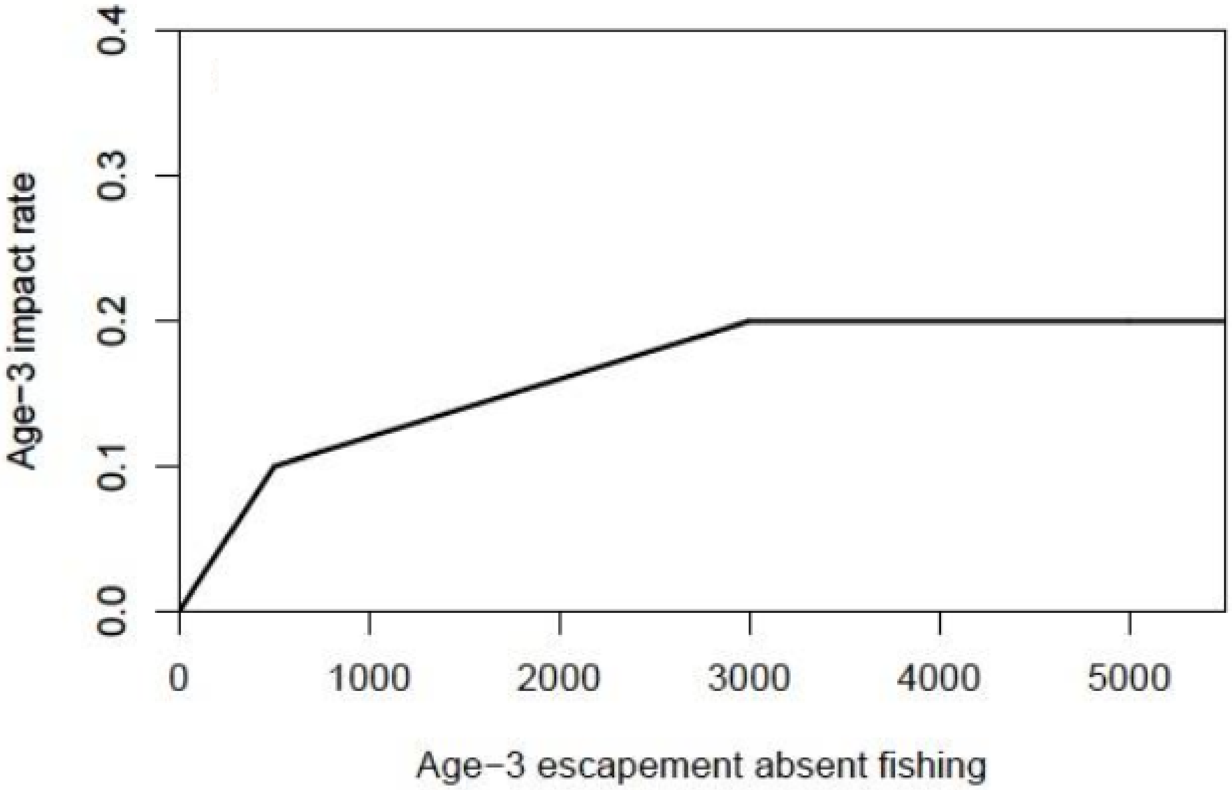

Figure 7.4. Sacramento River winter Chinook Salmon impact rate control rule. The maximum forecast age-3 impact rate for the area south of Point Arena, California, is determined by the forecasted age-3 escapement in the absence of fishing.

7.4.7 River Mouth Closures

Existing state and federal salmon fishing regulations set annual river mouth closures to protect salmon as they congregate outside their natal rivers and prepare for their inland migration. California regulates set closure areas centered on the mouths of the Klamath, Smith, and Eel rivers which prohibit commercial and recreational fishing during certain times of the year. Federal regulations prohibit commercial salmon fishing year-round in the Klamath Control Zone, an area of 12 square nautical miles centered around the Klamath River mouth, as well as in the area of coastline between the Humboldt South Jetty and Horse Mountain. These closures serve as a powerful management measure by protecting sensitive times and areas where certain stocks, which were once widely dispersed throughout the mixed-stock ocean fishery, become more concentrated and are more easily susceptible to fishing.

7.4.8 Additional Protective Measures

The Salmon FMP and ESA consultation standards work together to provide a management framework by defining conservation objectives, harvest control rules, and by setting caps on ocean harvest rates and impact rates. However, the PFMC has the responsibility to consider additional external factors that may affect abundance as part of the annual management process. These factors may include critically low escapement numbers for natural area spawning fish, poor indicators for marine and freshwater environmental conditions such as El Niño cycles and drought, and stock status determinations such as stocks in an overfished or approaching overfished condition. Given the specific current year circumstances, the PFMC may determine that additional conservative measures beyond those outlined in the Salmon FMP and ESA consultation standards are necessary to limit harvest and fishing opportunity on certain stocks.

As an example, fishing seasons have been restricted beyond minimum conservation objectives in recent years due to the overfished status determination for SR fall Chinook Salmon and UKTR fall Chinook Salmon, the main stocks supporting California’s ocean fisheries. The state’s most recent drought combined with poor ocean conditions led to three consecutive years of low escapement of spawning adults, resulting in both stocks being classified as overfished in 2017. During the 2018 and 2019 fisheries planning process, the PFMC designed ocean salmon fisheries to result in higher numbers of returning spawning fish for SR fall Chinook Salmon, beyond the minimum requirements of the FMP conservation objectives. This decision resulted in lost fishing opportunity and reduced harvest in hopes of expediting the rebuilding process.

Together, FMP guidelines and ESA consultation standards have a confounding effect on limiting harvest across the California coast. Management objectives can act independently to limit fishery impacts to specific stocks in particular times and areas or can be additive to provide protections for many stocks across time and space. Because weak stocks and abundant stocks are intermingled in the mixed-stock ocean fishery, fishery restrictions can provide umbrella protections for multiple stocks of salmon during the marine portion of their life cycle, and by extension, protection of UKTR spring Chinook Salmon.

7.5 Disease

In the Klamath River, a valuable management tool for the prevention of disease in Chinook Salmon is the use of special flow releases from reservoirs. Conditions conducive to ich and columnaris outbreaks, as occurred in 2002, are usually seen in late summer and early fall, when water temperatures tend to be high and water flows low. Low water flows and high water temperatures can impede fish passage and cause fish to congregate at high density. Low water flows also concentrate pathogens, while increased temperatures may increase pathogen reproduction rates. Higher densities of fish and pathogens increase the likelihood of pathogens contacting susceptible fish hosts. Increasing water releases from upstream reservoirs flush out pathogens before they contact susceptible fish and promotes upstream spawning fish migration, spreading susceptible host fish more widely through the river system (Strange 2012).

In 2017 the U.S. Department of the Interior released a “Record of Decision” (ROD) enacting a “Long-Term Plan to Protect Adult Salmon in the Lower Klamath River.” The decision allows releases of stored Trinity River water to ameliorate high stream temperature and low flows in the Lower Klamath River during late summer. High stream temperature and low flows were principle environmental conditions thought to have caused a severe outbreak of ich and columnaris that lead to the historic lower Klamath fish kill in 2002. The ROD is predicated on adaptive management and real time monitoring of flow, temperature, fish densities and pathogen levels.

Special release flows may also be useful to alleviate the effects of the pathogen *Ceratonova shasta*. *C. shasta* has a complex life cycle requiring a polychaete worm intermediate host. The intermediate host releases actinospores which are infective to fish. Decomposition of infected fish releases myxospores, which infect the polychaete intermediate host. The intermediate host tends to proliferate in areas of high sediment and nutrient deposition. Large water releases that provide a sediment scouring effect may help control infected polychaete populations through the removal of sediment. Increased spring flows may also provide for actinospore dilution and disruption, resulting in lower infection rates of out-migrating juvenile salmon. Fall water pulses result in myxospore redistribution and stranding, and possibly carcass stranding, which may result in lower numbers of infective myxospores reaching the intermediate host worms (Hillemeier 2017).

Other management strategies to decrease disease include prohibiting transportation between drainages, or importation, of infected, diseased, or parasitized fish. Regular health monitoring of hatchery production fish is currently performed to detect disease. Chemotherapeutics and antibiotics may be used to control external parasites and bacteria, and systemic bacterial infections. Best management practices should be used to avoid infectious agents and stressful conditions. Monitoring of hatchery broodstock for bacterial kidney disease (BKD), by fluorescent antibody testing of ovarian fluid, is helpful to reduce the incidence of this disease in Klamath-Trinity hatcheries.

7.6 Fisheries and Habitat Restoration and Management Plans

This section lists existing and/or historical restoration and management plans focused on or applicable to restoration or recovery of UKTR spring and fall Chinook Salmon in the Klamath basin.

7.6.1 Fish and Fish Habitat Restoration Plans:

Action Plan for Restoration of the South Fork Trinity River Watershed – A 1994 plan for adaptive management and restoration of anadromous fish populations in the South Fork Trinity River. http://www.krisweb.com/biblio/sft_usbor_pwa_1994_sftplan/pwa1.htm

Klamath basin Integrated Fisheries Restoration and Monitoring – An in-development adaptive management framework for planning the restoration and recovery of native fish species in the Klamath basin while improving flows, water quality, habitat, and ecosystem processes. http://kbifrm.psmfc.org/

Klamath Dam Decommissioning and Removal Project – A plan for decommissioning and removal of four hydroelectric dams on the mainstem Klamath River. Dam removal is scheduled to begin in 2022.
https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_quality_cert/lower_klamath_ferc14803.html

Klamath Tribes Wetland and Aquatic Resources Program Plan – Describes developing a program to reintroduce endangered suckers and Chinook Salmon to historic spawning locations in the Upper Klamath sub-basin. https://www.epa.gov/sites/production/files/2015-10/documents/tkt_final_warpp.pdf

Long Range Plan for the Klamath River basin Conservation Area Fishery Restoration Program – Developed in 1991 by the defunct Klamath River Basin Fisheries Task Force, this adaptive management plan was intended to develop policies that would help restore anadromous fish in the Klamath basin. http://www.krisweb.com/biblio/gen_usfws_kierassoc_1991_lrp.pdf

Reintroduction of Anadromous Fish in the Upper Klamath basin – A 2008 plan by the Oregon Department of Fish and Wildlife to modify their existing basin fishery plans to include reintroduction of anadromous fish, including UKTR spring Chinook Salmon, to the Upper Klamath sub-basin.
https://nrimp.dfw.state.or.us/nrimp/information/docs/fishreports/Klamath%20Reintroduction%20Plan_Final_Commission%20Adopted%202008.pdf

Salmon River Floodplain and Mine Tailing Habitat Restoration and Enhancement Plan – A 2018 technical memo by Stillwater Sciences evaluated opportunities and constraints for restoring floodplain and fluvial processes in the Salmon River. https://srrc.org/publications/programs/habitatrestoration/Salmon%20River%20Floodplain%20Enhancement%20Tech%20Memo_Final%202018.pdf

Salmon River Sub-basin Restoration Strategy: Steps to Recovery and Conservation of Aquatic Resources – A 2002 strategic plan for targeting collaborative restoration and protection efforts to restore the biological, geologic, and hydrogeologic processes that shape the quality of aquatic habitat. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5110056.pdf

Trinity River Restoration Program – Founded to address concerns over the impact of Central Valley Project activities on the mainstem Trinity River and its fish, the Trinity River Restoration Program is intended to manage sediment, restore watershed processes, improve infrastructure, and monitor and manage the river adaptively. https://www.trrp.net/program-structure/background/rod/

7.6.2 Land/Water Use and Water Quality Management Plans:

Klamath Basin Monitoring Program – This program implements, coordinates, and collaborates on water quality monitoring and research throughout the Klamath basin. http://www.kbmp.net/

Klamath Basin Restoration Program – A partnership between the U.S. Department of the Interior and the National Fish and Wildlife Federation to support basin-wide restoration projects to benefit fish. https://www.nfwf.org/programs/klamath-basin-restoration-program?activeTab=tab-1

Klamath Forest Plan – This document describes the U.S. Forest Service’s plan for managing the Klamath National Forests, which occupy a considerable percentage of land in the Klamath basin. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5333197.pdf

Salmon River TMDL and Implementation Plan – This is a plan to address and mitigate temperature issues in the Salmon River Watershed, consistent with the federal Clean Water Act. https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/Salmon_river/

Scott River Watershed Restoration Strategy and Schedule – This document is an assessment and plan for riparian protection, enhancement, and restoration in the Scott River watershed, developed for the Scott River Watershed Council and the Siskiyou RCD. https://a87cd223-4955-4835-9ecf-57ed24f1aaaa.filesusr.com/ugd/87211c_aa57af3fdf4445afa6f21109dcccac36.pdf

Western Klamath Restoration Partnership: A Plan for Restoring Fire Adapted Landscapes – This is a planning effort to guide collaborative fire management in the Western Klamath landscape.

http://karuk.us/images/docs/dnr/2014%20Western%20Klamath%20Restoration%20Partnership_Restoration%20Plan_DRAFT_FINA%20%20%20.pdf

7.6.3 Plans for Other Species That May Also Benefit UKTR Spring and Fall Chinook Salmon:

Fisheries Management Plan (FMP) and Amendments: Fisheries Management and Rebuilding Plans for the Pacific Fishery Management Council – This is the plan for managing ocean fisheries, including monitoring and limits to protect stocks. UKTR spring Chinook Salmon are a non-target stock for PFMC fisheries, but they are likely affected by protections for fall run. https://www.pcouncil.org/Salmon/fishery-management-plan/adoptedapproved-amendments/

Klamath River Fall Chinook Rebuilding Plan https://www.pcouncil.org/wp-content/uploads/2019/08/1_KRFC-RP_Final_070319.pdf

Recovery Strategy for California Coho Salmon – Document to guide the process of recovering Coho Salmon on the north and central coasts of California, including the Klamath basin. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=99401&inline

Southern Oregon and Northern California Coasts (SONCC) Salmon Recovery Plan – Developed to guide implementation of prioritized actions needed to conserve and recovery of the Southern Oregon/Northern California coast Coho Salmon ESU. www.westcoast.fisheries.noaa.gov/protected_species/Salmon_steelhead/recovery_planning_and_implementation/southern_oregon_northern_california_coast/SONCC_recovery_plan.html

7.7 Gravel Extraction

In 1991, the California Department of Conservation’s Division of Mine Reclamation (DMR) was created to provide a measure of oversight for local governments as they administer the Surface Mining and Reclamation Act (SMARA) of 1975 throughout California. Local Lead Agencies, such as counties administer SMARA with oversight from DMR and their Lead Agency Review and Assistance Program through vetted reclamation plans, annual mine inspections, review of financial assurance cost estimates and uniform application of mining laws and regulations. Reclamation plans are further subject to the California Environmental Quality Act and local land use code; Clean Water Act Section 401 (State Certification of Water Quality) and Section 404 (U.S. Army Corp of Engineers) that regulate the discharge of dredged or fill material into the waters of the United States. Instream gravel mining is subject to, and projects could be authorized by a Lake or Streambed Alteration Agreement (Fish and Game Code Section 1600 *et seq*.). Consultation with the NMFS and/or the Department pursuant to State and Federal ESA may also be warranted. As described, contemporary gravel mining is a highly regulated activity subject to multiple jurisdictions, but methodologies do vary by county and are based on site-specific conditions.

7.8 Suction Dredging

Suction dredging traditionally entails the use of a gasoline powered pump mounted onshore or on a floating platform that excavates (via suction) streambed material (rock, gravel, sand and fine sediment) into a sluice box or across a settling table where gold concentrates and settles out by gravity, then discharges gravel and water back into the stream as unconsolidated tailings. The dredging equipment is often positioned over the extraction area by securing the platform to rock or riparian trees with ropes or cables. A diver typically operates the flexible intake hose (3-12-inch diameter) over a portion of the stream bottom, excavating to a depth of two meters or more, and disturbance areas can range between a few small excavations to the entire wetted area in a section of a stream, including the banks (Harvey and Lisle 1998). Large suction dredges have the capacity to excavate as much as several cubic yards of gravel from the river bottom, depending on the type of streambed material and the operator (Horizon Water and Environment 2012). Current statutory definitions in California are much broader than traditional suction dredging. (See Fish & G. Code, § 5653, subd. (g); Wat. Code, Section 13172.5, subd. (a).)

Suction dredging has been shown to be detrimental to both biotic (Horizon Water and Environment 2012; Griffith and Andrews 1981; Thomas 1985; Harvey 1986) and abiotic stream process (Horizon Water and Environment 2012; Harvey and Lisle 1998) and the severity of the impact can be widespread and, in some cases such as streambanks, lasting. Suction dredging is common during the summer months in many river systems in western North America (Harvey and Lisle 1998). In some streams, salmonids do not emerge from the substrate until summer, and non-salmonids have protracted spawning periods extending into summer (Moyle 1976). UKTR spring Chinook Salmon enter the Klamath River between March and July and spawn between late August and September (Myers at al. 1998), at the peak of low flow and height of summer temperatures. For this reason, impacts to UKTR spring Chinook Salmon may be greater than to UKTR fall Chinook Salmon. In locations such as the Salmon River where UKTR spring Chinook Salmon persist in small numbers, suction dredging would likely entrain and cause mortality of early life stages such as incubating embryos and juvenile fish (Harvey and Lisle 1998).

Suction dredging and in-water mining generally is subject to regulation by both the federal government and the State of California, including on federal land. Suction dredging and in-water mining is subject to regulation by the federal government pursuant to the U.S. General Mining Law of 1872, and the federal Clean Water and Endangered Species Acts, among other federal laws. Suction dredging as defined by state law is subject to regulation in California under the Fish and Game and Water Codes. (See, e.g., Wat. Code, § 13172.5.) State law administered by the Department prohibits the use of vacuum and suction dredge equipment in California rivers, lakes, and streams, except as authorized by permit issued by the Department pursuant to Fish & G. Code Section 5653. The Department administers its related permitting program pursuant to regulations implementing Section 5653. (Cal. Code Regs., tit. 14, §§ 228, 228.5.) Notwithstanding Section 5653 and the Department's related regulations, the use of vacuum or suction dredge equipment, again as defined by state law, has been prohibited as a temporary matter by separate statute since August 2009. (Fish & G. Code, § 5653.1, subd. (b).) Legislation enacted by the State of California in 2015 amending Fish and Game Code Section 5653 and adding Section 13172.5 to the Water Code created a path for the 2009 interim moratorium to lift with additional regulatory and permitting actions by the Department and the State Water Resources Control Board (SWRCB), respectively. (See Stats. 2015, ch. 680 (Sen. Bill 637, Allen), §§ 2-3.) Under the legislation, however, the Department may not issue any permits under Fish and Game Code section 5653 until SWRCB or an appropriate Regional Water Quality Control Board completes a related water quality permitting effort, which is underway but not yet final. (*Id.*, § 5653, subd. (b)(1).) Under current state law, accordingly, the use of vacuum or suction dredge equipment is unlawful in California rivers, streams, and lakes, and any such activity is subject to enforcement and prosecution as a criminal misdemeanor. (See generally Fish & G. Code, §§ 5653, 5653.1, 12000, subd. (a).)

7.9 Habitat Restoration and Watershed Management

Early habitat monitoring in the Klamath basin dates to the early 20th Century (ESSA 2017). These early efforts were fragmented and focused on specific local issues and did not always monitor habitat in relation to fish. However, as fish populations have declined, monitoring efforts have become more coordinated and focused on known stressors.

Early habitat restoration in the Klamath-Trinity basin focused on instream structure whereas more recent work addresses fundamental causes of watershed impairment. Although some efforts still focus on one target species (e.g., certain anadromous salmonids), most restoration projects now aim to improve overall health of the watershed. Kier and Associates (1999) note that gradual progress has been made towards improving watershed function.

Federal, state and local agencies involved in substantial habitat restoration projects in the basin include: National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), the U.S. Forest Service, Natural Resource Conservation Service (part of the U.S. Department of Agriculture), Bureau of Reclamation, and the U.S. Environmental Protection Agency (USEPA), Oregon Department of Fish and Wildlife (ODFW), Oregon Department of Environmental Quality (ODEQ), the California Department of Fish and Wildlife, the California State Wildlife Conservation Board, and the California North Coast Regional Water Quality Control Board (NCRWQCB). Agencies administer restoration grant programs (e.g., Fisheries Restoration Grants Program, NMFS and the Department). Tribal governments also develop and carry out fish habitat and water quality restoration plans for tribal lands.

Restoration work in the region fall into the following categories: fish passage, screening, hatcheries, instream flow restoration, instream habitat restoration, riparian habitat restoration, upland habitat and sediment management, water quality restoration (including nutrient in-flow reduction) and wetland restoration. The number of grant-driven restoration projects examined in ESSA (2017) declined in the last decade; however, spending has increased, suggesting a shift towards fewer but more intensive restoration projects.

The distribution of different restoration projects varies over the basin. Activities associated with fish passage improvement and hatcheries are most commonly found in sub-basins below dams. These projects provide benefits to anadromous fish and are concentrated in the Lower Klamath basin. Instream flow monitoring, instream habitat improvement, riparian restoration, and sediment reduction that watershed-level benefits to a range of aquatic and terrestrial species are distributed more evenly across all sub-basins. A large concentration of riparian restoration projects is also found in the Upper Klamath River.

Projects focused on reducing sediment inputs through management of uplands and roads and riparian restoration projects receive the most funding (ESSA 2017). The largest proportion of total restoration spending and projects have been in the lower Klamath and mid/upper Klamath sub-basin where anadromous fish still have access and existing dams strongly impact habitat quality and quantity.

7.10 Research and Monitoring Programs

Research and monitoring programs in the Klamath basin are in place to support fishery management and recovery of listed and sensitive species. Management is based on ESA and CESA provisions and regulatory actions and funding for restoration focus on ESA-listed species, Species of Special Concern, and fisheries. Management for ESA-listed suckers and Coho Salmon are important elements of the Klamath Irrigation Project operations and Iron Gate Dam operations under the NMFS 2013 Biological Opinion. Many of the recovery plans for species in the basin include adaptive management of recovering populations as an explicit objective, while some recovery plans have a secondary goal of restoring harvest opportunities (ESSA 2017).

The Klamath basin is large and monitoring aquatic species across the entire basin is complex. More than 32 organizations conduct monitoring in 12 Klamath sub-basins. Fish restoration in the Klamath basin has recently shifted from many disconnected projects to a more unified approach. A collaborative group was assembled in the process of developing the Klamath Basin Restoration Agreement and the Klamath Hydroelectric Settlement Agreement. The Klamath Basin Monitoring Program took steps toward a basin-wide monitoring plan. Although existing monitoring is substantial, development of large-scale coordinated monitoring plans with standardized methods that include random/spatially balanced sampling and coordinated reporting would greatly improve the usefulness of monitoring data in the basin.

Within the Klamath basin, there are at least 15 major programs to monitor habitat (including water quality), 14 to monitor fish populations, and nine to monitor the effectiveness of restoration projects. A recent review (ESSA 2017) found that most monitoring is focused on habitat status and trend, followed by population monitoring. Monitoring the effectiveness of restoration projects is less common.

8. Summary of Listing Factors

8.1 UKTR Spring Chinook Salmon as a Separate ESU

The petitioners assert that new information on the association of a specific chromosome region with run timing in UKTR spring Chinook Salmon is enough to classify them as distinct from UKTR fall Chinook Salmon and from the combined UKTR Chinook Salmon ESU. This status review finds that the referenced genomic association (see petition and Prince et al. 2017) with early migration timing is a significant distinguishing feature of the two (spring and fall) ecotypes. However, the Department judges that this novel genomic association, while illuminating an allele at a specific gene region for early migration, is not necessary to demonstrate differences between UKTR spring and fall Chinook Salmon under CESA. Other well-established ecological, life-history, and behavioral differences between UKTR spring and fall Chinook Salmon are sufficient to define them as "different" at some level. The Department has traditionally managed the UKTR spring and fall Chinook Salmon ecotypes differently, with more protections for UKTR spring Chinook Salmon (e.g., inland fishing regulations, placement on the California Species of Special Concern). Regardless of our judgement that there are differences between UKTR spring and fall Chinook Salmon, the Department agrees with other analyses (e.g., Myers et al. 1998; Williams et al. 2011, 2013) that the distinction between UKTR spring and fall Chinook Salmon is most appropriately placed at the level of ecotypes, and that the two combined ecotypes form an interbreeding ESU.

UKTR spring Chinook Salmon are not currently considered a DPS or ESU under federal guidelines. Although UKTR spring Chinook Salmon are qualitatively different in some ways from UKTR fall Chinook Salmon, warranting the label of ecotype, they are not reproductively isolated from fall Chinook Salmon and mix with them on spawning grounds. UKTR spring and fall Chinook Salmon ocean distribution also overlaps substantially.

The *GREB1L/ROCK1* gene region has been shown to contain elements strongly associated with early migration timing in UKTR Chinook Salmon. UKTR spring and fall Chinook Salmon, and importantly, other Chinook Salmon in California and elsewhere (Anderson and Garza 2019, Narum et al. 2018) possess different forms of this gene region. Homozygotes for the "spring" allele at this gene region are associated with early migration timing (Prince et al. 2017, Thompson et al. 2020). Heterozygotes are present in the Klamath-Trinity system; however, heterozygotes may not be present in large proportions in all parts of the system, perhaps especially in the Klamath River and tributaries, and individuals with spring run timing may be selected against under current conditions. Selection is likely against early arrival and holding that are characteristic of the UKTR spring Chinook Salmon ecotype. Heterozygotes likely act as a reservoir of "spring" alleles, albeit at low frequency.

8.2 Summary of Listing Factors

CESA directs the Department to prepare this report regarding the status of UKTR spring Chinook Salmon based upon the best scientific information available to the Department.

CESA's implementing regulations identify key factors that are relevant to the Department's analyses. Specifically, a "species shall be listed as endangered or threatened ... if the Commission determines that its continued existence is in serious danger or is threatened by any one or any combination of the following factors: present or threatened modification or destruction of its habitat, overexploitation, predation, competition, disease, or other natural occurrences or human-related activities (Cal. Code Regs., tit. 14, § 670.1, subd. (i)(1)(A).

The petitioners assert that the UKTR spring Chinook Salmon is a distinct ESU and is in danger of extinction due to:

- present or threatened modification of its habitat;
- disease; and
- other natural events or human related activities.

The following summarizes the Department's determination regarding the factors to be considered by the Commission in making its decision on whether to list UKTR spring Chinook Salmon as a distinct ESU. This summary is based on the best available scientific information, as presented in the foregoing sections of this status review. Because the best scientific evidence shows that UKTR spring Chinook Salmon are an ecotype of the larger UKTR Chinook Salmon ESU (spring and fall), this status review considers listing factors in relation to the combined ESU.

This status review concludes the following:

1. The best available science does not support the UKTR spring Chinook Salmon as its own ESU separate from the currently defined UKTR Chinook Salmon ESU comprising both spring and fall ecotypes.

2. **Present or threatened modification or destruction of habitat:** Dam construction and other habitat modifications (e.g., historical mining, land and water use) in the Klamath basin have resulted in truncated and fragmented distribution of the UKTR Chinook Salmon ESU in comparison to historical times. The UKTR spring Chinook Salmon ecotype was likely more common and more widely distributed within the basin historically due to conditions that favored expression of the early returning phenotype. Although current distribution of the spring ecotype is fragmented and abundance is low, distribution and abundance of the UKTR Chinook Salmon ESU as a whole is not. The UKTR spring Chinook Salmon ecotype is currently found in small to moderately large numbers in the basin, with notable spawning aggregations in three disjunct locations—

Salmon River on the Klamath, Upper Trinity River, and South Fork Trinity River. UKTR spring Chinook Salmon in the Salmon River and the South Fork Trinity River are less abundant than in the Upper Trinity River. In comparison, UKTR fall Chinook Salmon (and therefore the UKTR Chinook ESU as a whole) are widely distributed in the basin in relatively large numbers.

Four Klamath River dams are planned for removal starting in 2022 if permits are received on schedule. Removal of these dams will allow anadromous fish access to previously blocked spawning and rearing areas upstream into Oregon. The UKTR Chinook ESU, especially UKTR fall Chinook Salmon, abundant in the Klamath River, are expected to benefit from access to this expanded upstream habitat. However, UKTR spring Chinook Salmon, whose only consistent current representation in the Klamath River is in the Salmon River, likely do not exist in high enough numbers and are too far down in the drainage to expect them to rapidly naturally repopulate the Upper Klamath. The Department does not know with any certainty whether or how the spring ecotype will naturally respond to dam removal. At the same time, the Department believes that recovery potential for UKTR spring Chinook Salmon and other anadromous fish is much more likely without the dams.

Although habitat alteration in the basin has been extensive, the UKTR Chinook Salmon ESU remains widely distributed and in large numbers. Therefore, the Department does not consider the continued existence of the UKTR Chinook Salmon ESU to be in serious danger or threatened by present or threatened modification or destruction of habitat.

3. **Overexploitation:** Current ocean commercial and sport fisheries do not discriminate UKTR spring fall Chinook Salmon from UKTR fall Chinook Salmon. Also, direct estimates for natural-origin UKTR spring Chinook Salmon ocean catch are not feasible; however, marked and tagged TRH UKTR spring Chinook Salmon can be used to estimate ocean fishing impacts to the spring ecotype. Most UKTR Chinook Salmon (both spring and fall ecotypes) are harvested in the Klamath Management Zone and Fort Bragg areas, but the highest harvest index is in the Central Oregon zone. The commercial fishery accounts for the majority of UKTR spring Chinook Salmon ocean catch. Catch is split evenly between Oregon and California. Ocean harvest of hatchery UKTR spring Chinook Salmon is small in comparison to that for UKTR fall Chinook Salmon and other Chinook Salmon stocks.

   Except when *de minimus* fisheries are authorized, UKTR fall Chinook Salmon are managed for a conservation floor target of 40,700 natural area adults annually. The overall harvest rate is determined by the PFMC with NMFS guidance on an annual basis resulting in impact rates to the stock designed to achieve the conservation escapement target. Ocean fisheries are structured by area and season and in-river by quotas to target the overall impact rate cap. In-river harvest, both recreational and tribal, are governed by quotas determined by the PMFC that target in-river escapement objectives.

Tribal quotas tend to be higher than in-river sport quotas because most of the non-tribal allocation is apportioned to ocean fisheries. UKTR spring and fall Chinook Salmon are important cultural and nutritional Klamath tribal fisheries. The Hoopa Valley and Yurok tribal long-term annual average harvest is about 4,000 UKTR spring Chinook Salmon. The Yurok tribal harvest is usually greater than the Hoopa tribal harvest. Recent total tribal harvest numbers have declined to approximately 1,000+ UKTR spring Chinook Salmon.

Sport harvest of UKTR spring Chinook Salmon has declined both in relation to peak harvest in the mid-1980s and again since 2012. On average, sport harvest is larger in the Trinity basin than the Klamath basin. Overall sport harvest of UKTR spring Chinook Salmon is moderate in comparison to combined population component size in both the Klamath and Trinity rivers. Larger harvest in the Upper Trinity River at current levels is likely supportable due to the presence of generally larger numbers there and the presence of hatchery-origin UKTR spring Chinook Salmon from TRH. There is currently no harvest of UKTR spring Chinook Salmon in the Salmon River; however, given the low abundance of UKTR spring Chinook Salmon found in that river, fisheries in the lower Klamath River that impact Salmon River spring Chinook Salmon deserve more scrutiny.[16]

Although the UKTR fall Chinook Salmon are currently considered overfished by the PFMC, overall numbers of the UKTR Chinook Salmon ESU remain relatively high. Therefore, the Department does not consider the continued existence of the UKTR Chinook Salmon ESU to be in serious danger or threatened by overexploitation.

4. **Predation:** UKTR Chinook Salmon are preyed upon by a variety of natural and introduced predators. However, predation is not thought to be a primary factor causing declines in UKTR Chinook Salmon. Pinniped predation on UKTR Chinook Salmon may be an added stressor for UKTR Chinook Salmon; however, pinniped predation alone does not considerably affect the ability of the UKTR Chinook Salmon ESU to survive and reproduce. The number of combined UKTR Chinook Salmon from fall and spring ecotypes remains large and distributed across the basin. Therefore, the Department does not consider the continued existence of the UKTR Chinook Salmon ESU’s to be in serious danger or threatened by predation.

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[16] Current regulations as a result of UKTR spring Chinook Salmon CESA candidacy provide additional take restrictions, e.g., no harvest until July 1 on the lower Klamath and upper Trinity rivers. Historically, spring chinook harvest was allowed January through Aug 14 on the lower Klamath River and January through August 30 on the upper Trinity River. These restrictions may be modified if the Commission determines the listing is not warranted.

5. **Competition:** Non-native and native salmonids and hatchery-origin fish may compete with UKTR Chinook Salmon when times and areas overlap; however, the effects of these and many of the invasive species in the basin are uncertain, as little quantitative information exists to evaluate their possible impacts. Evidence of large numbers of the combined UKTR Chinook Salmon ESU suggest that, while competition may be a limiting factor at some level, it does not pose a serious threat to continued existence of the ESU. Therefore, the Department does not consider the continued existence of the UKTR Chinook Salmon ESU to be in serious danger or threatened by competition.
6. **Disease:** Juvenile and adult fish kills have been common in the Klamath River. The parasite *C. shasta* is implicated in high juvenile mortality. Columnaris infections and associated low flows that concentrate fish and disease vectors have affected Chinook Salmon abundance in the Klamath. Measures are in place to reduce and control disease and proposed dam removal may substantially decrease disease impacts. UKTR Chinook Salmon ESU abundance remains high in the face of substantial disease issues in the drainage.

   Dam removal, planned to begin in 2022 if permits are received on schedule, has the potential to change the ecological setting (flows) in a way that selects against some disease organisms. Although speculative, disease organisms and their impacts on anadromous fish may be very different, possibly less than at present, under restored river flow conditions.

   Therefore, while an area of concern for overall productivity of the ESU, the Department does not consider the continued existence of the UKTR Chinook Salmon ESU to be in serious danger or threatened by disease.

7. **Other natural occurrences or human-related activities:** Climate change projections for the Klamath basin predict warmer water temperatures during the summer and fall that will likely affect habitat suitability for salmonids including UKTR spring Chinook Salmon. How this future projection will be affected by dam removal is not known. Marine survival is strongly influenced by ocean climate patterns that vary on annual and decadal or longer scales. Ocean cycles will continue to affect annual abundance and timing of salmonids in the region. Drought is expected to be a periodic stressor across the state. The UKTR Chinook Salmon spring ecotype is likely more vulnerable than the fall ecotype to a warming climate and drought because of their migration timing and time spent in-river; however, the potential for climate change to increase the threat to continued existence of the UKTR Chinook Salmon ESU is not known for certain.

   Hatcheries in the region produce large numbers of UKTR fall Chinook Salmon and more modest numbers of UKTR spring Chinook Salmon. Hatchery fish are likely to have both positive and negative effects on natural-origin UKTR Chinook Salmon. Most hatchery influence appears to be in the vicinity of the hatchery. Because only TRH produces UKTR spring Chinook Salmon, spring hatchery fish mostly impact the Upper Trinity River UKTR spring Chinook Salmon spawning aggregation, and to a lesser degree, the South Fork Trinity River spawning aggregation. Hatchery strays to the Salmon River and other parts of the Trinity River are uncommon. The UKTR fall Chinook Salmon programs at TRH and IGH currently supplement fall abundance throughout the drainage. The UKTR spring Chinook Salmon program at TRH supplements the spring ecotype, mostly in the upper Trinity River. Rough estimates of Proportionate Natural Influence (PNI) for the Upper Trinity River UKTR spring Chinook Salmon group does not currently meet accepted conservation guidelines for protection of natural stocks. Data are not available to allow PNI calculations throughout the drainage; however, UKTR spring Chinook Salmon PNI is likely much higher in areas distant from TRH. Future UKTR fall Chinook Salmon production at IGH is uncertain because of the potential dam removal and dewatering of the hatchery.

Human-related activities likely affect overall UKTR Chinook Salmon ESU productivity; however, due to the large abundance of the UKTR Chinook Salmon ESU, the Department does not consider the continued existence of the UKTR Chinook Salmon ESU to be in serious danger or threatened by other natural occurrences or human-related activities.

9. Protections Afforded by CESA Listing

It is the policy of the state to conserve, protect, restore, and enhance any endangered or threatened species and its habitat (Fish & G. Code, § 2052). The conservation, protection, and enhancement of listed species and their habitat is of statewide concern (Fish & G. Code, § 2051(c)). If listed, unauthorized take of UKTR spring Chinook Salmon would be prohibited under state law. Under CESA “take” is defined as to hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill a listed species (Fish & G. Code, § 86). Any person violating the take prohibition would be punishable under state law. The Fish and Game Code provides the Department with related authority to authorize “take” of species listed as threatened or endangered under certain circumstances (see, e.g., Fish & G. Code, §§ 2081, 2081.1, 2086, & 2835). In general, and even as authorized, however, impacts of the taking caused by the activity must be minimized and fully mitigated according to state standards.

Cooperative management with the federal government may be complicated by inconsistent management frameworks if the state lists a group different than the federally-recognized ESU.

If the UKTR spring Chinook Salmon is listed under CESA, take impacts resulting from activities authorized through incidental take permits must be minimized and fully mitigated according to state standards (Fish & G. Code, § 2081, subd. (b)). These standards typically include protection of land in perpetuity with an easement, development and implementation of a species-specific adaptive management plan, and funding through an endowment to pay for long-term monitoring and maintenance to ensure the mitigation land meets performance criteria. Obtaining an incidental take permit is voluntary. The Department cannot force compliance; however, any person violating the take prohibition may be criminally and civilly liable under state law. Research and monitoring in watersheds populated by UKTR spring Chinook Salmon would be regulated by issuance of permits or memorandums of understanding under Fish and Game Code Section 2081, subdivision (a).

Additional protection of UKTR spring Chinook Salmon following listing would be expected to occur through state and local agency environmental review under the California Environmental Quality Act (CEQA). CEQA requires affected public agencies to analyze and disclose project-related environmental effects, including potentially significant impacts on rare, threatened, and endangered species. In common practice, potential impacts to listed species are examined more closely in CEQA documents than potential impacts to unlisted species. Where significant impacts are identified under CEQA, the Department expects project-specific avoidance, minimization, and mitigation measures to benefit the species. State listing, in this respect, and consultation with the Department during state and local agency environmental review under CEQA, would be expected to benefit the UKTR spring Chinook Salmon in terms of reducing impacts from individual projects, which might otherwise occur absent listing.

CESA listing may prompt increased interagency coordination specific to UKTR spring Chinook Salmon conservation and protection and the likelihood that state and federal land and resource management agencies will allocate additional funds toward protection and recovery actions. In the case of the UKTR spring Chinook Salmon, some multi-agency efforts to protect the spring ecotype already exist due to regional interest in maintaining the spring ecotype, and the department’s recognition of the importance of the ecotype to diversity of the UKTR Chinook Salmon ESU. CESA listing could result in increased priority for limited conservation funds.

In addition, listing of UKTR spring Chinook Salmon could increase priority and available funding for recolonization efforts proposed for the ecotype post-dam removal. It should be noted that these activities will likely occur regardless of UKTR spring Chinook Salmon listing status (see *Sections 12 Alternatives to Listing, 13 Recovery Considerations, and 14 Management Recommendations*).

10. Degree and Immediacy of Threat

Genetic and other biological evidence show that UKTR spring Chinook Salmon are a polyphyletic group without substantial population genetic distinction from UKTR fall Chinook Salmon. Although UKTR spring Chinook Salmon exhibit genetic and ecological differences from UKTR fall Chinook Salmon, these differences are at the level of an ecotype, not a separate ESU. Based on the available evidence the Department concludes that the combination of UKTR spring and fall Chinook Salmon into a combined UKTR Chinook Salmon ESU is valid and justifiable. Although spawning fish abundance estimates for the entire basin are incomplete, available data and analyses suggest that extinction risk at the UKTR Chinook Salmon ESU-level is low.

Based on long- and short-term evaluations, and climate warming predictions, it seems likely that UKTR spring Chinook Salmon in the Salmon and South Fork Trinity rivers could be extirpated as an ecotype in those places, and that extirpation could progress rapidly. However, because the "spring allele" is present in other locations in the basin (most notably in the UKTR spring Chinook Salmon groups from the Upper Trinity and TRH) and elsewhere, it is possible that the ecotype could be reintroduced if conditions change or if assisted conservation actions that favor UKTR spring Chinook Salmon (e.g., active reintroduction and introduction of spring alleles) are taken.

Accurate assessment of the degree and immediacy of threat to the UKTR Chinook Salmon ESU is further complicated by the planned removal of four dams on the Klamath River, currently scheduled to begin 2022 assuming that permits are granted by that time. Dam removal will open large spawning and rearing areas that have been blocked to UKTR Chinook Salmon for decades. Dams have been cited in this and other reviews as a major limiting factor for UKTR spring Chinook Salmon. Because of their abundance and distribution in the basin, UKTR fall Chinook Salmon (and steelhead) may rapidly and naturally colonize the Upper Klamath River. However, because of the small number of UKTR spring Chinook Salmon present in only one place In the Klamath River basin (mostly in the Salmon River) and the distance to the nearest more abundant UKTR spring Chinook Salmon spawning assemblage (Upper Trinity River and TRH), unassisted natural recolonization of the Upper Klamath by UKTR spring Chinook Salmon post dam removal seems likely to take a long time. Especially in the Klamath River, more immediate actions designed to introduce spring-returning fish with early-return alleles will likely be necessary for colonization to occur in conservation-relevant timeframes.

Based on the considerations outlined above, overall, the Department believes the degree and immediacy of threat for the combined UKTR Chinook Salmon ESU is low. However, immediate conservation actions are necessary for protection and enhancement of the UKTR spring Chinook salmon ecotype portion of the UKTR Chinook Salmon ESU (see suggested actions in *Section 12 Alternatives to Listing, 13 Recovery Considerations,* and *14 Management Recommendations*).

11. Listing Recommendation

In response to the listing petition received by the California Fish and Game Commission, CESA directs the Department to prepare a status review report for UKTR spring Chinook Salmon using the best scientific information available. (Fish & G. Code, § 2074.6.) CESA also directs the Department to recommend whether the petitioned action is warranted. (Fish & G. Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f).)

Under CESA, an endangered species is defined as "a native species or subspecies…which is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease." (Fish & G. Code, § 2062.) A threatened species is defined as "a native species or subspecies…that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by [CESA]." (Fish & G. Code, § 2067.)

The Department's status review recommendation is submitted to the Commission in an advisory capacity based on the best available science. In consideration of the scientific information contained herein, the Department recommendation is that UKTR spring Chinook Salmon should not be listed as a threatened or endangered species under the CESA. The Department arrives at this recommendation based on the following:

1. The petitioners request that the Commission list UKTR spring Chinook Salmon as endangered based on its qualification as a new ESU. Based on the best scientific information available at this time, the Department has determined that UKTR spring Chinook Salmon do not qualify as a separate ESU. UKTR spring Chinook Salmon are not reproductively isolated from UKTR fall Chinook Salmon. Genetic diversity in the UKTR Chinook Salmon ESU is structured by geography more than by run timing. The UKTR spring Chinook Salmon are best described as an ecotype, or genetic diversity element, of the combined UKTR Chinook Salmon ESU.
2. The UKTR Chinook Salmon ESU's continued existence is not in serious danger or threatened by habitat modification. Although substantial habitat modification has occurred in the Klamath basin, and those modifications have affected UKTR Chinook Salmon, the UKTR Chinook Salmon are widely distributed in both the Klamath and Trinity Rivers in large numbers.
3. The UKTR Chinook Salmon ESU's continued existence is not in serious danger or threatened by overexploitation. Although the fall stock is considered overfished by the PFMC, the overall numbers of fish in the ESU continue to be large. Both in-river and ocean fisheries are managed for minimum abundance in the tens of thousands.
4. The UKTR Chinook Salmon ESU's continued existence is not in serious danger or threatened by predation. There are numerous predators of UKTR Chinook Salmon, including native and non-native fish species, and pinnipeds; however, predation is not

thought to be a limiting factor for the ESU. Overall, abundance of the combined UKTR Chinook Salmon ESU is large.

5. The UKTR Chinook Salmon ESU’s continued existence is not in serious danger or threatened by competition. Evidence of large numbers of the combined UKTR Chinook Salmon ESU suggest that, while competition may be a limiting factor at some level, it does not pose a serious threat to continued existence of the ESU.
6. The UKTR Chinook Salmon ESU’s continued existence is not in serious danger or threatened by disease. Juvenile and adult fish kills are common in the Klamath River. However, management actions are in place to reduce their effect. Proposed dam removals may reduce incidence and severity of disease outbreaks. Although disease is a concern due to its effect on total productivity of the ESU, disease does not pose a serious threat to continued existence of the ESU.
7. Human-related activities likely affect overall UKTR Chinook Salmon ESU productivity. However, due to the large abundance of the UKTR Chinook Salmon ESU, the Department finds that the UKTR Chinook Salmon ESU’s continued existence is not in serious danger or threatened by other natural occurrences or human-related activities.

12. Alternatives to Listing

If the Commission determines that listing is not warranted, the UKTR spring Chinook Salmon will revert to the unlisted status under state law that it held prior to the petition filing. Although unlisted, UKTR spring Chinook Salmon would continue to be on the list of Species of Special Concern. Projects with the potential to take UKTR spring Chinook Salmon will not be required to obtain State incidental take permits; however, the existing federal and state permit requirements that existed prior to the petition filing will remain in place. For example, the state will continue to negotiate Streambed Alteration Agreements and comment on Timber Harvest Plans, federal incidental take permits and recovery planning (if UKTR spring Chinook Salmon are listed under the ESA), and applications to the State Water Resources Control Board. Also, the Department of Fish and Wildlife will continue to act as the trustee agency for the state's fish, wildlife, and plant resources. In this role, the Department will review and comment on impacts to UKTR spring Chinook Salmon and recommend mitigation measures for these impacts as part of the CEQA review process.

In the absence of a decision by the Commission to list UKTR spring Chinook Salmon, the Department would also continue to participate in and support current or future programs designed to benefit UKTR spring Chinook Salmon and other anadromous fish including: coordination with other agencies on removal of four dams on the Klamath River (currently scheduled to begin 2022), participation on forums guiding and advising IGH operations and modifications pre- and post-Klamath dam removal, implementing recommendations of the CA HSRG (2012) for Trinity River Hatchery, coordination of operations supporting artificial propagation of UKTR spring and fall Chinook Salmon at TRH, coordination with ODFW on a reintroduction plan for the Upper Klamath River post-dam removal, prevention and treatment of disease, development and implementation of Hatchery and Genetic Management Plans, coordination with state agencies to decrease impacts from timber related projects, continue efforts to improve habitat for UKTR spring Chinook Salmon, identify/removing/retrofitting existing barriers to fish passage, working with gravel extractors and other mining interests to avoid, minimize, or mitigate for impacts to fisheries resources, continuing to restore and enhance salmon and steelhead habitat throughout the state through the Fisheries Restoration Grants Program and other granting programs, participation in federal and state conservation and restoration programs operating in the petitioned area, regulation of UKTR spring Chinook Salmon inland sport fishing, regulation and monitoring of ocean salmon fisheries, conducting research and monitoring programs, and coordinating with other agency research and monitoring efforts.

13. Recovery Considerations

The Department's recovery objective for UKTR spring Chinook Salmon is to protect and expand existing natural-origin spawning populations and reestablish enough additional native populations in restored and protected streams to ensure persistence over a minimum 100-year time frame. Increased numbers, expanded distribution, and metapopulation development will improve their probability of long-term survival within their native range in the Klamath Basin. Recovery actions would focus on 1) restoring, rehabilitating, and protecting habitat in natural spawning areas, and 2) improving conservation hatchery elements at Trinity River Hatchery in support of natural UKTR spring Chinook Salmon recovery, in accordance with state statute and Commission and Department policies.

The current plan to remove four large dams on the Klamath River, a massive change in the Klamath River ecosystem, contributes substantial uncertainty about UKTR spring Chinook Salmon natural recovery potential. Overall, dam removal that results in a free-flowing river should be positive for all aquatic species in the basin.

State statute and Commission policy places management emphasis and priority on natural rather than hatchery-origin stocks. For example, Fish and Game Code Section 6901 states:

- Proper salmon and steelhead trout resource management requires maintaining adequate levels of natural, as compared to hatchery, spawning and rearing.
- Reliance upon hatchery production of salmon and steelhead trout in California is at or near the maximum percentage that it should occupy in the mix of natural and artificial hatchery production in the state. Hatchery production may be an appropriate means of protecting and increasing salmon and steelhead in specific situations; however, when both are feasible alternatives, preference shall be given to natural production.
- The protection of, and increase in, the naturally spawning salmon and steelhead trout of the state must be accomplished primarily through the improvement of stream habitat.

Also, the Commission policy on Cooperatively Operated Rearing Programs for Salmon and Steelhead states: “The bulk of the state’s salmon and steelhead resources shall be produced naturally. The state’s goals of maintaining and increasing natural production take precedence over the goals of cooperatively operated rearing programs.” The Commission policy on salmon states that “salmon shall be managed to protect, restore, and maintain the populations and genetic integrity of all identifiable stocks. Naturally spawned salmon shall provide the foundation for the Department’s management program.”

Recovery also mandates effective monitoring of long-term status and trend of UKTR spring Chinook Salmon abundance and distribution throughout the petitioned area, as well as within sub-watersheds, is necessary. Recovery goals must ensure that individual populations and collective metapopulation(s), are sufficiently abundant to avoid genetic risks of small population size. Therefore, these goals need to address abundance levels (adult spawning escapements), population stability criteria, distribution, and length of time for determining sustainability.

If listed under CESA, the Department will develop appropriate down listing or delisting criteria for UKTR spring Chinook Salmon, based on the best scientific information available. The department will periodically reexamine the status of UKTR spring Chinook Salmon. When, in the Department's judgment, recovery goals and down listing or delisting criteria have been met, the department will make recommendations to the Commission regarding changing the status of this species.

Recovery of viable UKTR spring Chinook Salmon in the Klamath basin will require vigorous efforts by the Department, basin Tribes, other government agencies, and the private sector to improve and expand habitat and support expanded distribution of the spring ecotype. Watershed, water flow and quality, and habitat conditions must be improved to provide the necessary spawning and rearing habitat to allow the natural UKTR spring Chinook Salmon population components to survive, diversify, and increase to levels sufficient to withstand droughts, unfavorable climatic and oceanic conditions, and other uncontrollable natural phenomena.

Reintroduction and expansion of naturally reproducing UKTR spring Chinook Salmon, especially in the restored (i.e., post-dam removal) Klamath River, may require artificial propagation (i.e., conservation hatchery operations). These activities would be conducted under Department authority in cooperation with federal, local, and tribal governments and stakeholders. Trinity River Hatchery already produces UKTR spring Chinook Salmon and, if necessary, could be either 1) modified to include a conservation hatchery element, or 2) modified to develop a separate program focused on UKTR spring Chinook Salmon conservation.

14. Management Recommendations

Regardless of whether the Commission decides to list UKTR spring Chinook Salmon as a threatened or endangered species under CESA, the Department recommends the following management changes to support existing small and fragmented UKTR spring Chinook Salmon population components:

1. Investigate use of *GREB1L/ROCK1* genes for genetic stock identification in both ocean and inland fisheries. Collection and analysis of genetic data have high potential to provide information about abundance and ocean distribution of both natural- and hatchery-origin UKTR spring Chinook Salmon.
2. Implement monitoring of *GREB1L/ROCK1* genetic markers TRH Chinook salmon broodstock to verify the transition timing of UKTR spring and fall Chinook salmon.
3. Develop and implement a plan, within the framework of existing biological opinions, to add a conservation hatchery element to the UKTR spring Chinook Salmon program at TRH. This could either be a modification of the existing program to include conservation elements, or a separate smaller program focusing on conservation of the spring ecotype.
4. Implement CA HSRG (2012) recommendations for Trinity River Hatchery's UKTR spring and fall Chinook Salmon programs through the existing multiagency, multidisciplinary Hatchery Coordination Team.
5. Develop conservation hatchery strategies to increase the abundance of UKTR spring Chinook salmon in the Klamath River consistent with the goals of reintroduction plans.
6. Develop a monitoring plan for UKTR spring Chinook Salmon natural recovery in the Klamath River post dam removal.
7. Continue coordination with ODFW on a salmonid reintroduction plan, especially for UKTR spring Chinook Salmon, for the Klamath River post dam removal.
8. Consider implementing the California Coastal Monitoring Plan (CMP; Adams et al. 2011) for UKTR spring and fall Chinook Salmon in both the Klamath and Trinity rivers to obtain robust and unbiased estimates of both UKTR spring and fall Chinook Salmon status and trend throughout the basin.
9. Implement measures to improve the proportion of natural-origin fish used as broodstock in TRH's UKTR spring Chinook Salmon hatchery program and measures to reduce the proportion of hatchery-origin fish on natural spawning grounds in the Upper Trinity River such that the Proportionate Natural Influence (PNI) is at least 0.67 in accordance with CA HSRG (2012) guidelines.
10. Implement one of the following marking/tagging strategies for UKTR spring and fall Chinook Salmon at TRH: a) 100% CWT and adipose fin-flip, or b) the CA HSRG recommendation of 100% CWT and 25% adipose fin-clip. Alternatively, consider implementation of 100% Parental Based Tagging (PBT) to replace or augment CWTs as a tagging method. Some studies (e.g., Anderson and Garza 2006, Steele et al. 2013) have shown that PBT may be more efficient and equally effective as 100% CWT.

11. Consider development of a mark-select fishery for in-river spring sport harvest in the Upper Trinity River to reduce hatchery-origin fish numbers on natural spawning grounds. This would likely require 100% adipose fin-clip marks for all TRH UKTR spring Chinook Salmon. Mark selective fisheries can have substantial negative impacts to natural-origin fish and should only be implemented with extreme caution.

We also recommend adoption and implementation of the following management recommendations proposed in Moyle et al. (2015):

12. Follow-through with plans to remove mainstem Klamath River dams;
13. Restore cold-water refugia on the Shasta River;
14. Continue to manage the Salmon River as a refuge for UKTR spring Chinook Salmon (and summer steelhead),
15. Develop and implement in-hatchery and in-stream monitoring to assess TRH hatchery impacts on natural stocks;
16. Accelerate habitat restoration to mitigate impacts from roads and logging; and
17. Revisit ocean and inland harvest to consider specific impacts to UKTR spring Chinook Salmon.

15. Economic Considerations

The Department is charged in an advisory capacity to the Fish and Game Commission to provide a written status review report and a resultant recommendation based on the best scientific information available regarding the status of the UKTR spring Chinook Salmon in California. The Department is not required to prepare an analysis of economic impacts (See Fish & G. Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f)).

Literature Cited

Adams, P. B., L. B. Boydstun, S. P. Gallagher, M. K. Lacy, T. McDonald, and K. E. Shaffer. 2011. California coastal salmonid population monitoring: strategy, design, and methods. California Department of Fish and Game Fish Bulletin 180.

Allen, M. A. 2000. Seasonal microhabitat use by juvenile spring Chinook Salmon in the Yakima River basin, Washington. Rivers 7(4):314-322.

Allendorf, F. W., P. A. Hohenlohe, and G. Luikart. 2010. Genomics and the future of conservation genetics. Nature Reviews Genetics 11:697-709.

Anderson, E. C., M. J. Ford, J. C. Garza and J. D. Kiernan. 2018. Upper Klamath and Trinity River Chinook Salmon ESU- configuration Review - panel report, A report to the National Marine Fisheries Service West Coast Region – Protected Resources Division from Southwest Fisheries Science Center, 110 McAllister Way, Santa Cruz, CA 95060.

Anderson, E. C., M. J. Ford, J. C. Garza, and J. D. Kiernan. 2019. Upper Klamath and Trinity River Chinook Salmon ESU-Configuration Review-Panel Report. Report from Southwest Fisheries Science Center to West Coast Region, Protected Resources Division. Update of 15 June 2018 report. 24 April 2019. NMFS Southwest Fisheries Science Center, 110 McAllister Way, Santa Cruz, CA 95060.

Anderson, E. C., and J. C. Garza. 2006. The power of single-nucleotide polymorphisms for large-scale parentage inference. Genetics, 172(4): 2567–2582.

Anderson, E. C., and J. C. Garza. 2019. Supplemental and recent findings pertinent to ESU configuration of the Upper Klamath Trinity River Chinook salmon ESU, A report to the National Marine Fisheries Service West Coast Region – Protected Resources Division from Southwest Fisheries Science Center, Santa Cruz, CA.

Augerot, X., and D.N. Foley. 2005. Atlas of Pacific Salmon. Pp. 80-83. University of California Press, Berkeley.

Banks, M., and M. Barton. 1999. Microsatellite DNA variation among Klamath River Chinook salmon sampled from fall and spring runs. Yurok Tribe Fisheries Program. Klamath, CA.

Banks, M., M. Barton, and P. Berrebi. 2000a. Microsatellite DNA variation among Klamath River chinook Salmon. Final Report, submitted to Yurok Tribe Fisheries Program. Klamath, CA.

Banks, M. A., V. K. Rashbrook, M. J. Calavetta, C. A. Dean, and D. Hedgecock. 2000b. Analysis of microsatellite DNA resolves genetic structure and diversity of chinook salmon in California's Central Valley. Canadian Journal of Fisheries and Aquatic Sciences 57:915-927.

Barnhart, R. A. 1994. Salmon and steelhead populations of the Klamath-Trinity Basin, California. Pages 73-97 in T. J. Hassler, editor. Klamath Basin fisheries symposium. California Cooperative Fishery Research Unit, Humboldt State University, Arcata, CA.

Barnhart, R. A., and D. C. Hillemeier. 1994. Summer habitat utilization by adult spring Chinook Salmon and summer steelhead, South Fork Trinity River, California. Final Report, California Cooperative Fishery Research Unit, Humboldt State University, Arcata, CA.

Barr, B. R., M. E. Koopman, C. D. Williams, S. J. Vynne, R. Hamilton, and B. Doppelt. 2010. Preparing for climate change in the Klamath Basin. National Center for Conservation Science & Policy and The Climate Leadership Initiative.

Bartholow, J. M. 2005. Recent water temperature trends in the Lower Klamath River, California. North American Journal of Fisheries Management 25:152-162.

Beer, W. N., and E. A. Steel. 2018. Impacts and Implications of temperature variability on Chinook Salmon egg development and emergence phenology. Transactions of the American Fisheries Society 147:3-15.

Belchik, M. 1997. Summer locations and salmonid use of cool water areas in the Klamath River. Iron Gate Dam to Seiad Creek, 1996. Yurok Tribal Fisheries Program. Klamath, CA.

Bjornn, T. C. 1969. Embryo survival and emergence studies, Job. No. 5, Federal Aid in Fish and Wildlife Restoration. Job Completion Rep., Proj. F-49-R7. Idaho Fish and Game Department, Boise.

Bjornn, T. C., and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society. Special Publication 19:83-138.

Bourret, S. L., C. C. Caudill, M. L. Keefer. 2016. Diversity of juvenile Chinook Salmon life history pathways. Reviews in Fish Biology and Fisheries 26(3):375-403.

Buchanan, R., R. Townsend, J. Skalski, and K. Ham. 2011. The effect of bypass passage on adult returns of Salmon and steelhead: an analysis of PIT-tag data using the program ROSTER. Final Report. Prepared by Battelle, Pacific Northwest Division, Richland, Washington for U.S. Army Corps of Engineers, Walla Walla District, WA.

Buffington, J., C. Jordan, M. Merigliano, J. Peterson, and C. Stalnaker. 2014. Review of the Trinity River Restoration Program following Phase 1, with emphasis on the program's channel rehabilitation strategy. Prepared by the Trinity River Restoration Program's Science Advisory Board with assistance from Anchor QEA, LLC, Stillwater Sciences, BioAnalysts, Inc., and Hinrichsen Environmental Services. Accessed at: https://www.trrp.net/library/document/?id=2172

Busch, D. S., C. J. Harvey, P. McElhany. 2013. Potential impacts of ocean acidification on the Puget Sound food web. ICES J Mar Sci. 70(4):823–33. https://doi.org/10.1093/icesjms/fst061

Busch, D. S., P. McElhany. 2016. Estimates of the direct effect of seawater pH on the survival rate of species groups in the California Current ecosystem. PLoS ONE. 2016; 11(8):e0160669. Epub 2016/08/12.

Burns, J. W. 1972. Some effects of logging and associated road construction on northern California streams. Transactions of the American Fisheries Society 101:1-17.

California Department of Fish and Game (CDFG). 1965. California Fish and Wildlife Plan. Volume III, Supporting Data. Part B – Inventory salmon-steelhead and marine resources.

California Department of Fish and Game (CDFG). 1998. A status review of the spring-run Chinook Salmon (*Oncorhynchus tshawytscha*) in the Sacramento River drainage. Candidate Status Report 98-01. California Department of Fish and Game (Wildlife), Sacramento CA.

California Department of Fish and Game (CDFG). 2002. Status review of California Coho Salmon north of San Francisco. Report to The California Fish and Game Commission. April 2002.

California Department of Fish and Game (CDFG). 2003. September 2002 Klamath River fish kill: Preliminary analysis of contributing factors special report. California Department of Fish and Game (Wildlife), Northern Region, Redding CA.

California Department of Fish and Game (CDFG). 2004. September 2002 Klamath River Fish-Kill: Final Analysis of Contributing Factors and Impacts. California Department of Fish and Game (Wildlife), Northern Region, Redding CA.

California Department of Fish and Game (CDFG). 2011a. Klamath River basin fall Chinook salmon spawner escapement, in-river harvest and run-size estimates, 1978–2010. Available from W. Sinnen, CDFG, 5341 Ericson Way, Arcata, CA 95521.

California Department of Fish and Game (CDFG). 2011b. Klamath River basin spring Chinook salmon spawner escapement, in-river harvest and run-size estimates, 1980–2009. Available from W. Sinnen, CDFG, 5341 Ericson Way, Arcata, CA 95521.

California Department of Fish and Wildlife (CDFW). 2015. Klamath River Basin spring Chinook Salmon spawner escapement, river harvest and run-size estimates, 1980 – 2014. Accessed at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=100231

California Department of Fish and Wildlife (CDFW). 2018a. Statewide drought response: stressor monitoring summary 2014-2017. California Department of Fish and Wildlife, Fisheries Branch. Sacramento, CA. Available from: http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=168170

California Department of Fish and Wildlife (CDFW). 2018b. Evaluation of the petition from the Karuk Tribe and the Salmon River Restoration Council to list Upper Klamath Trinity River spring Chinook Salmon (*Oncorhynchus tshawytscha*) as threatened or endangered. A report to the California Fish and Game Commission. November 2018.

California Department of Fish and Wildlife (CDFW). 2019. Annual report Trinity River basin salmon and steelhead monitoring project: Chinook and Coho Salmon and fall-run steelhead run-size estimates using mark recapture methods, 2018 – 19 Season. California Department of Fish and Wildlife, Northern Region, Klamath-Trinity Program. July 2019.

California Hatchery Scientific Review Group (CA HSRG). 2012. California hatchery review report. Prepared for the U.S. Fish and Wildlife Service and Pacific States Marine Fisheries Commission. April 2012.

Campbell, A., and P. B. Moyle. 1991. Historical and recent population sizes of spring-run Chinook Salmon in California. Pages 155-216 in T.J. Hassler, editor. Proceedings, Northeast Pacific Chinook and Coho Salmon Workshop. American Fisheries Society, Arcata, CA.

Carter, K., and S. Kirk. 2008. Fish and fishery resources of the Klamath River basin. 2008. Appendix 5 *in* North Coast Regional Water Quality Control Board. 2010. Final staff report for the Klamath River Total Maximum Daily Loads (TMDLs) addressing temperature, dissolved oxygen, nutrient, and microcystin impairments in California. The proposed site-specific dissolved oxygen objectives for the Klamath River in California and the Klamath River and Lost River Implementation plans. California Water Boards, North Coast Region, Santa Rosa, CA. Accessed at: https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/klamath_river/

Chaffin, B., R. K. Craig, and H. Gosnell. 2015. Resilience, adaptation, and transformation in the Klamath River basin socio-ecological system. 51 Idaho Law Review: 157-193.

Chamberlain, C. D., S. Quinn, and B. Matilton. 2012. Distribution and abundance of Chinook Salmon redds in the mainstem Trinity River 2002 – 2011. U.S. Fish and Wildlife Service.

Arcata Fisheries Technical Report TR 2012-16. Accessed at: https://www.fws.gov/arcata/fisheries/reports/technical/Trinity_redd_2002_to_2011.pdf

Chiaramonte, L. V., R. A. Ray, R. A. Corum, T. Soto, S. L. Hallett, and J. L. Bartholomew. 2016. Klamath river thermal refuge provides juvenile Salmon reduced exposure to the parasite *Ceratonova shasta*. Transactions of the American Fisheries Society 145:810-820.

Clemento, A. J., E. D. Crandall, J. C. Garza, and E. C. Anderson. 2014. Evaluation of a single nucleotide polymorphism baseline for genetic stock identification of Chinook Salmon (*Oncorhynchus tshawytscha*) in the California Current large marine ecosystem. Fishery Bulletin 112(2-3):112-130.

Cline, T. J., J. Ohlberger, and D. E. Schindler. 2019. Effects of warming climate and competition in the ocean for life-histories of Pacific salmon. Nature Ecology & Evolution 3:935–942.

Coates, D. J., M. Byrne, and C. Moritz. 2018. Genetic diversity and conservation units: dealing with the species-population continuum in the age of genomics. Frontiers in Ecology and Evolution 6:165.

Coots, M. 1962. Shasta River, Siskiyou County, 1958 King Salmon count, with yearly totals from 1930-1961. California Department of Fish and Game, Inland Fisheries Branch, Sacramento, California.

Crête-Lafrenière, A., L. Weir., and L. Bernatchez. 2012. Framing the Salmonidae family phylogenic portrait: a more complete picture from increased taxon sampling. PLoS one. 7. E6662. 10.1371/journal.pone.0046662.

Crozier, L. G., M. M. McClure, T. Beechie, S. J. Bograd, D. A. Boughton, M. Carr, et al. 2019. Climate vulnerability assessment for Pacific salmon and steelhead in the California Current Large Marine Ecosystem. PLoS ONE 14(7): e0217711. https://doi.org/10.1371/journal.pone.0217711

Curran, M. A. J., T. D. van Ommen, V. I. Morgan, K. L. Phillips, and A. S. Palmer. 2003. Ice core evidence for Antarctic Sea ice decline since the 1950s. Science 302(5648):1203–1206.

Dean, M. 1996. Life history, distribution, run size, and harvest of spring Chinook Salmon in the South Fork Trinity Chapter VII, Annual Report, Trinity River Basin salmon and steelhead monitoring project, 1994 – 1995 season. California Department of Fish and Game, Inland Fisheries Division Sacramento.

De la Fuente, J. and P. A. Haessig, 1993, Salmon Sub-Basin Sediment Analysis, USDA – Forest Service, Klamath National Forest.

Dennis, B., P. L. Munholland, and J. M. Scott. 1991. Estimation of growth and extinction parameters for endangered species. Ecological Monographs 61:115-143.

Elder, D., B. Olson, A. Olson, J. Villeponteaux, and P. Brucker. 2002. Salmon River subbasin restoration strategy: steps to recovery and conservation of aquatic resources. Prepared by Klamath National Forest, Yreka California and Salmon River Restoration Council, Sawyers Bar, California for the Klamath Basin Restoration Task Force.

Eschmeyer, W. N., W. W. Herald, and H. Hammann. 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Co., Boston, MA.

ESSA Technologies, Ltd. (ESSA). 2017. Klamath Basin Integrated Fisheries Restoration and Monitoring (IFRM) Synthesis Report. Pacific States Marine Fishery Commission, Portland, OR.

Federal Energy Regulatory Commission (FERC). 2007. Final Environmental Impact Statement for Hydropower License, Klamath Hydroelectric Project, FERC Project No. 2082-027, FERC/EIS-0201F. Washington, D.C., Federal Energy Regulatory Commission, Office of Energy Projects, Division of Hydropower Licensing.

Fetcho, K. 2006. Water Year 2005, Klamath River Blue-Green Algae Bloom Report. Yurok Tribe Environmental Program. Klamath, CA.

Flagg, T. A., B. A. Berejikian, J. E. Colt, W. W. Dickhoff, L. W. Harrell, D. J. Maynard, C. E. Nash, M. E. Strom, R. N. Iwamoto, and C. V. W. Mahnken. 2000. Ecological evaluation of the effect of hatcheries on wild salmon and behavioral impacts of artificial production strategies on the abundance of wild salmon populations—a review of practices in the Pacific Northwest. NOAA Technical Memorandum NMFS-NWFSC-41. U.S. Department of Commerce, Seattle, Washington.

Foott, J. S., D. Free, W. Talo, and J. D. Williamson. 1997. FY96 Investigational Report: physiological effects of *Nanophyetus Metacercaria* infection in Chinook Salmon smolts (Trinity River). U. S. Fish and Wildlife Service, California- Nevada Fish Health Center, Anderson, CA.

[17]Ford, M., K. Nichols, R. Waples, E. C. Anderson, M. Kardos, I. Koch, G. McKinney, M. R. Miller, J. Myers, K. Naish, S. Narum, K. G. O'Malley, D. Pearse, T. Seamons, A. Spidle, P. Swanson,

---

[17] The Northwest Fisheries Science Center of NOAA's National Marine Fisheries Service uses the NOAA Processed Report NMFS-NWFSC-PR series to disseminate information only. Manuscripts have not been peer-reviewed and

T. Q. Thompson, K. Warheit, and S. Willis. 2020. Reviewing and Synthesizing the State of the Science Regarding Associations between Adult Run Timing and Specific Genotypes in Chinook Salmon and Steelhead: Report of a workshop held in Seattle, Washington, 27–28 February 2020. U.S. Department of Commerce, NOAA Processed Report NMFS-NWFSC-PR-2020-06.

Fortune, J. D., A. R. Gerlach, and C. J. Hanel. 1966. A study to determine the feasibility of establishing salmon and steelhead in the Upper Klamath Basin. Oregon State Game Commission and Pacific Power and Light Company. Portland, OR.

Fraser, D. J., and L. Bernatchez. 2001. Adaptive evolutionary conservation: towards a unified concept for defining conservation units. Molecular Ecology 10:2741-2752.

Fresh, K. L., and S. L. Schroder. 1987. Influence of the abundance, size, and yolk reserves of juvenile Chum Salmon (*Oncorhynchus keta*) on predation by freshwater fishes in a small coastal stream. Canadian Journal of Fisheries and Aquatic Sciences 44(2):236-243.

Fuhrman, A. E., D. A. Larsen, E. A. Steel, G. Young, and B. R. Beckman. 2017. Ecology of Freshwater Fishes 2017:1-13.

Garza, J. C., S. M. Blankenship, C. Lemaire, and G. Charrier. 2007. Genetic population structure of Chinook Salmon (*Oncorhynchus tshawytscha*) in California’s Central Valley. Final report: CalFed Project “Comprehensive evaluation of population structure and diversity for Central Valley Chinook Salmon”.

Good, T. P., R. S. Waples, and P. Adams. 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. NOAA Technical Memorandum NMFS-NWFSC-66.

Goodman, D. H., A. Meartin, J. Alvarez., A. Davis, and J. Palos. 2010. Assessing Trinity River salmonid habitat at channel rehabilitation sites, 2007 – 2008. U.S. Fish and Wildlife Service, Yurok Tribe, and Hoopa Valley Tribe. June 2010.

Gresh, T., J. Lichatowich, and P. Schoonmaker. 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 25:15-21.

---

may be unedited. Documents within this series represent sound professional work, but do not constitute formal publications. They should only be footnoted as a source of information and may not be cited as formal scientific literature. The data and any conclusions herein are provisional, and may be formally published elsewhere after appropriate review, augmentation, and editing. NWFSC Processed Reports are available from the NOAA Institutional Repository, https://repository.library.noaa.gov.

Griffith, J. S., and D. A. Andrews. 1981. Effects of a small suction dredge on fishes and aquatic invertebrates in Idaho streams. North American Journal of Fisheries Management 1:21-28.

Hamilton, J. B., G. L. Curtis, S. M. Snedaker, and D. K. White. 2005. Distribution of anadromous fishes in the upper Klamath River watershed prior to hydropower dams – a synthesis of historical evidence. Fisheries 30(4):10-20.

Hamilton, J. B., D. Rondorf, M. Hampton, R. Quinones, J. Simondet, and T. Smith. 2011. Synthesis of the effects to fish species of two management scenarios for the secretarial determination on removal of the lower four dams on the Klamath. Prepared by the Biological Subgroup for the Secretarial Determination Regarding Potential Removal of the Lower Four Dams on the Klamath River.

Hamilton, J. B., D. W. Rondorf, W. T. Tinniswood, R. J. Leary, T. Mayer, C. Gavette, and L. A. Casal. 2016. The persistence and characteristics of Chinook Salmon migrations to the upper Klamath River prior to exclusion by dams. Oregon Historical Quarterly 117: 326–377.

Hampton, M. 1997. Microhabitat suitability criteria for anadromous Salmonids of the Trinity River. U.S. Fish and Wildlife Service, Arcata, CA.

Hardy, T. B., and R. C. Addley. 2006. Evaluation of interim instream flow needs in the Klamath River, Phase II, Final Report. Report prepared for USDI. Institute for Natural Systems Engineering. Utah Water Research Laboratory. Utah State University. Logan UT.

Hart, J. L., 1973. Pacific fishery of Canada. Fisheries Research Board of Canada Bulletin 180:740.

Harvey, B. C. 1986. Effects of suction gold dredging on fish and invertebrates in two California streams. North American Journal of Fisheries Management 6:401-409.

Harvey, B. C., and T. E. Lisle. 1998. Effects of suction dredging on streams: a review and an evaluation strategy. North American Journal of Fisheries Management 8:8-17.

Harvey, C., T. Garfield, G. Williams, N. Tolomieri (eds.). 2019. California current integrated ecosystem assessment (CCIEA). California current ecosystem status report, 2019.PSMFC Agenda Item E.1.a. IEA Team Report. March 2019. Available at: https://www.pcouncil.org/documents/2019/02/agenda-item-e-1-a-iea-team-report-1-california-current-integrated-ecosystem-assessment-cciea-california-current-ecosystem-status-report-2019.pdf/

Hatchery Scientific Review Group (HSRG). 2015. Annual Report to Congress on the Science of Hatcheries, 2015. A report on the application of up-to-date science in the management of Salmon and steelhead hatcheries in the Pacific Northwest.

Hawthorne, N. 2017. Estimating hydraulic mining disturbance to the Salmon River using LiDAR. Prepared in fulfillment of the Humboldt State University course in Geospatial Science in Research. December

Healey, M. C. 1991. Life history of Chinook Salmon *(Oncorhynchus tshawytscha).* In C. Groot and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver, Canada.

Hearn, W. 1987. Interspecific competition and habitat segregation among stream-dwelling trout and salmon. Fisheries 12(5):24-31.

Hearsey, J. W., and A. P. Kinziger. 2015. Diversity in sympatric chinook salmon runs: timing, relative fat content and maturation. Environ Biol Fish 98:413–423.

Hess, J. E., J. S. Zendt, A. R. Matala, and S. R. Narum. 2016. Genetic basis of adult migration timing in anadromous steelhead discovered through multivariate association testing. Proceedings of the Royal Society B. 283:20153064.

Hillemeier, D. 1999. An assessment of pinniped predation upon fall-run Chinook Salmon in the lower Klamath River, CA, 1997. Yurok Tribal Fisheries Program. Klamath, CA. Accessed at: http://www.krisweb.com/biblio/klamath_yuroktfp_hillemeier_1997_pinnipeds.pdf

Hillemeier, D., and M. Farro. 1995. Final Report: Review and Evaluation of Horse Linto Creek Rearing Facility, 1985-1994. Arcata, CA.

Hillemeier, D., M. Belchik, T. Soto, S. Tucker, and S. Ledwin. 2017. Measures to reduce *Ceratonova shasta* infection of Klamath River salmonids: a guidance document. Disease Technical Advisory Team.

Horton, N. J., and K. P. Kleinman. 2007. Much ado about nothing: a comparison of missing data methods and software to fit incomplete data regression models. The American Statistician 61(1):79-90.

Horizon Water and Environment. 2012. Suction Dredge Permitting Program—Final Subsequent Environmental Impact Report. HWE 09.005. Oakland, CA.

Huntington, C. W. 2006. Estimates of anadromous fish runs above the site of Iron Gate Dam. Clearwater BioStudies, Canby, Oregon.

Huntington, C. W., E. W. Claire, F. A. Espinosa, Jr., and R. House. 2006. Reintroduction of anadromous fish to the Upper Klamath Basin: an evaluation and conceptual plan. Report to the Klamath Tribes and Yurok Tribes.

Independent Scientific Advisory Board (ISAB). 2005. Report on harvest management of Columbia basin salmon and steelhead. ISAB Harvest Report, ISAB 2005-4.

Integrated Hatchery Operations Team (IHOT) 1995. Policies and procedures for Columbia Basin anadromous salmonid hatcheries. Annual Report, 1994. Report to Bonneville Power Administration, Contract No. 1992B160629; BPA Report DOE/BP-60629. http://www.hatcheryreform.us/hrp/uploads/VAGREAJSVIM5/IHOT%20STANDARDS.pdf.

Intergovernmental Panel on Climate Change (IPCC). 2007. R. K. Pacharui and A. Reisinger, editors. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland. www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm.

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

Jacox, M. G., C. A. Edwards, E. L. Hazen, and S. J. Bograd. 2018. Coastal upwelling revisited: Ekman, Bakun, and improved upwelling indices for the U.S. west coast. Journal of Geophysical Research: Oceans 123:7332-7350.

Karuk Tribe and Salmon River Restoration Council. 2018. Petition to the State of California Fish and Game Commission to list Klamath Trinity spring Chinook under the CESA.

Katz, J., P. B. Moyle, R. M., Quiñones, J. Israel, S. Purdy. 2012. Impending extinction of salmon, steelhead, and trout (Salmonidae) in California. Environmental Biology of Fishes 96:1169-1186.

Kier and Associates. 1999. Mid-term evaluation of the Klamath River Basin Fisheries Restoration Program. Prepared for the Klamath River Basin Fisheries Task Force and USFWS. Yreka, CA.

Kinziger, A. P., M. Hellmair, and D. G. Hankin. 2008a. Genetic structure of Chinook Salmon (*Oncorhynchus tshawytscha*) in the Klamath-Trinity Basin: implications for within-basin genetic stock identification. Produced under contract agreement between the Hoopa Valley Tribal Fisheries Department and Humboldt State University Sponsored Programs Foundation. Project received financial support by U.S. Bureau of Reclamation, Klamath Basin Area Office. (Full contract title: GSI Klamath Chinook, project number 1.22-4275).

Kinziger, A. P., M. Hellmair, D. G. Hankin, and J.C. Garza. 2013. Contemporary population structure in Klamath River basin Chinook Salmon revealed by analysis of microsatellite genetic data. Transactions of the American Fisheries Society 14(5):1347-1357.

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

Klamath River Basin Fisheries Task Force (KRBFTF). 1991. Long Range Plan for The Klamath River Basin Conservation Area Fishery Restoration Program. Assistance from William M. Kier Associates.

Klamath River Technical Team (KRTT). 2011. Klamath River fall Chinook salmon age specific escapement, river harvest, and run size estimates, 2010 run. Available from the Pacific Fishery Management Council, 7700NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Koch, I. J., and S. R. Narum. 2020. Validation and association of candidate markers for adult migration timing and fitness in Chinook salmon. Evolutionary Applications. 13:2316-2332.

Kondolf, G. M., and M. G. Wolman. 1993. The sizes of salmonid spawning gravels. Water Resources Research 29(7):2275-2285.

Krawchuk, M. A., M. A. Moritz. M.A. Parisien, J. Van Dorn, and K. Hayhoe. 2009. Global pyrogeography: The current and future distribution of wildfire. PLOS One 4(4): e5102.

Laake, J. L., M. S. Lowry, R. L. DeLong, S. R. Melin, and J. V. Carretta. 2018. Population growth and status of California sea lions. Journal of Wildlife Management 82:583-595.

Lane and Lane Associates. 1981. The Copco dams and the fisheries of the Klamath Tribe. Prepared for the Bureau of Indian Affairs. US Department of the Interior. Portland, Oregon.

La Faunce, D. A. 1967. A king salmon spawning survey of the South Fork Trinity River, 1964. CA Dept. Fish and Game, Mar. Res. Admin. Rep. No. 67-10.

Lara, W. 1993-1996. Yurok Accelerated Stocking Program for Klamath River Late Run Fall Chinook. Walt Lara, Jr., Klamath California. Cited in: Pacific Watershed Associates (PWA). 1994. Action Plan for restoration of the South Fork Trinity River watershed and its fisheries. Prepared for the US Bureau of Reclamation and the Trinity River Task Force. Accessed at: http://www.krisweb.com/biblio/sft_usbor_pwa_1994_sftplan/pwa1.htm

Leidy, R. A., and G. R. Leidy. 1984. Life stage periodicities of anadromous salmonids in the Klamath River basin, northwestern California. US Fish and Wildlife Service, Sacramento, CA.

Lestelle, L. 2012. Effects of Dwinnell Dam on Shasta River salmon and considerations for prioritizing recovery actions. Karuk Tribe, Happy Camp, CA.

Leitritz, E. and E. Lewis 1976. Trout and salmon culture (hatchery methods). California Department of Fish and Game, Fish Bulletin 164.

Levin, P. S., R. W. Zabel, and J. G. Williams. 2001. The road to extinction is paved with good intentions: negative associations of fish hatcheries with threatened salmon. Proceedings of the Royal Society B 268:1153-1158.

Levins, R. 1969. Some demographic and genetic consequences of environmental heterogeneity for biological control. Bulletin of the Entomological Society of America 15(3):237-240.

Lichatowich, J. 1999. Salmon without rivers: a history of the Pacific salmon crisis. Island Press, Washington, D.C.

Lindley, S. T., C. B. Grimes, M. S. Mohr, W. Peterson, J. Stein, J. T. Anderson, L. W. Botsford, , D. L. Bottom, C. A. Busack, T. K. Collier, J. Ferguson, J. C. Garza, A. M. Grover, D. G. Hankin, R. G. Kope, P. W. Lawson, A. Low, R. B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F. B. Schwing, J. Smith, C. Tracy, R. Webb, B. K. Wells, and T. H. Williams. 2009. What caused the Sacramento River fall Chinook stock collapse? Pre-publication report to the Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Marine, K. R. and Cech, J. J. Jr., 2004, Effects of high water temperature on growth, smoltification, and predator avoidance in juvenile Sacramento River Chinook salmon: North American Journal of Fisheries Management, V. 24, p. 198–210.

Mathis, J. T., J. N. Cross, W. Evans, S. C. Doney. 2015. Ocean acidification in the surface waters of the Pacific-Arctic boundary regions. Oceanography. 28(2):122–35.

Matthews, K. R., and N. H. Berg. 1997. Rainbow trout responses to water temperature and dissolved oxygen stress in two southern California stream pools. Journal of Fish Biology, 50:50-67.

McClure, M. M., E. E. Holmes, B. L. Sanderson, and C. E. Jordan. 2003. A large-scale multispecies status assessment: anadromous salmonids in the Columbia River basin. Ecological Applications, 13(4): 964-989.

McCuddin, M. E. 1977. Survival of salmon and trout embryos and fry in gravel-sand mixtures. M.S. thesis, University of Idaho, Moscow, ID.

McPhail. J. D, and C. C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Bulletin - Fisheries Research Board of Canada. 173:381.

Meehan, W. R. (editor). 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication No. 19.

Meek, M. H., M. R. Baerwald, M. R. Stephens, A. Goodbla, M. R. Miller, K.M.H. Tomalty, and B. May. 2016. Sequencing improves our ability to study threatened migratory species: Genetic population assignment in California's Central Valley Chinook Salmon. Ecology and Evolution 6: 7706–7716.

Moffett, J. W. and S. E. Smith. 1950. Biological Investigations of the fishery resources of Trinity River, California. Special Scientific Report: Fisheries No. 12. United States Fish and Wildlife Service. Washington, D.C.

Moran, P., D. J. Teel, M. A. Banks, T. D. Beacham, M. R. Bellinger, S. M. Blankenship, J. R. Candy, J. C. Garza, J. E. Hess, S. R. Narum, L. W. Seeb, W. D. Templin, C. G. Wallace, and C. T. Smith. 2013. Divergent life-history races do not represent Chinook Salmon coast-wide: the importance of scale in Quaternary biogeography. Canadian Journal of Fisheries and Aquatic Sciences 70: 415–435

Moritz, C. 1994. Defining 'evolutionarily significant units' for conservation. Trends in Ecology and Evolution, 9:373-375.

Morrison, W., M. Nelson, J. Howard, E. Teeters, J. A. Hare, R. Griffis. 2015. Methodology for assessing the vulnerability of fish stocks to changing climate. National Marine Fisheries Service, Office of Sustainable Fisheries. Report No.: NOAA Technical Memorandum NMFS-OSF-3.

Morrow, J. E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing Co., Anchorage, AK.

Moyle, P. B. 1976. Inland fishes of California. University of California Press, Berkeley.

Moyle, P. B. 2002. Inland fishes of California. Second edition. University of California Press, Berkeley.

Moyle, P. B., J. A. Israel, and S. E. Purdy. 2008. Salmon, steelhead, and trout in California: status of emblematic fauna. A report commissioned by California Trout. Center for Watershed Sciences, University of California, Davis.

Moyle, P. B., J. V. E. Katz, R. M. Quiñones. 2011. Rapid decline of California's native inland fishes: A status assessment. Biological Conservation 144(2011):2414-2423.

Moyle, P. B., R. Lusardi, and P. Samuel. 2017. "SOS II: Fish in Hot Water." San Francisco, CA: California Trout. Accessed at: http://caltrout.org/sos/.

Moyle, P. B., R. M. Quiñones, J. V. Katz and J. Weaver. 2015. Fish Species of Special Concern in California. Sacramento: California Department of Fish and Wildlife.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. Fish species of special concern in California. Prepared by Department of Wildlife and Fisheries Biology, University of California, Davis for California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova.

Munday, P. L., D. L. Dixson, J. M. Donelson, G. P. Jones, M. S. Pratchett, G. V. Devitsina, K. B. Døving. 2009. Ocean acidification impairs olfactory discrimination and homing ability of a marine fish. Proceedings of the National Academy of Sciences of the United States of America. 106(6):1848–52.

Murphy, M. L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and Alaska- requirements for protection and restoration. National Oceanic and Atmospheric Administration, NOAA Coastal Ocean Program, Decision Analysis Series No. 7.

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neeley, 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.

Naish, K. A., J. E. Taylor III, P. S. Levin, T. P. Quinn, J. R. Winton, D. Huppert, and R. Hilborn. 2007. An evaluation of the effects of conservation and fishery enhancement hatcheries on wild populations of salmon. Advances in Marine Biology 53:61–194.

Narum, S. R., A. Di Genova, S. J. Michelletti, and A. Maass. 2018. Genomic variation underlying complex life-history traits revealed by genome sequencing in Chinook salmon. Proc. R. Soc. B 285: 20180935. http://dx.doi.org/10.1098/rspb.2018.0935

National Marine Fisheries Service. (NMFS). 1997. Investigation of scientific information on the impacts of California sea lions and Pacific harbor seals on salmonids and on the coastal ecosystems of Washington, Oregon, and California. U.S Department of Commerce, NOAA Technical Memorandum NOAA-NWFSC-28. Accessed at https://www.krisweb.com/biblio/gen_nmfs_nmfs_1997_tm28.pdf

National Marine Fisheries Service (NMFS). 2010. Biological opinion on the operation of the Klamath Project between 2010 and 2018. Prepared for Bureau of Reclamation by NOAA Fisheries Service, Southwest Region. Available at: http://swr.nmfs.noaa.gov/klamath/FINALKlamath_Ops_031510.pdf

National Marine Fisheries Service. (NMFS). 2013. Biological Opinion on the Effects of Proposed Klamath Project Operations from May 31, 2013, through March 31, 2023, on Five Federally Listed Threatened and Endangered Species. West Coast Regional Office ESA Section 7 Consultation.

National Marine Fisheries Service. (NMFS). 2014. Final Recovery Plan for the southern Oregon/northern California coast Evolutionarily Significant Unit of Coho Salmon (*Oncorhynchus kisutch*). National Marine Fisheries Service. Arcata, California. Accessed at: https://repository.library.noaa.gov/view/noaa/15985

National Marine Fisheries Service. (NMFS). 2018. National Oceanic and Atmospheric Administration, February 27, 2018. Endangered and Threatened Wildlife; 90-Day Finding on a petition to list Chinook Salmon in the Upper Klamath/Trinity rivers basin as threatened or endangered under the Endangered Species Act

National Marine Fisheries Service. (NMFS). 2019. Ecosystem Status Report of the California Current for 2019: A summary of ecosystem indicators compiled by the California Current Integrated Ecosystem Assessment Team (CCIEA). Accessed at: https://repository.library.noaa.gov/view/noaa/22658

National Research Council of the National Academies (NRC). 2004. Endangered and threatened fishes in the Klamath River basin. National Academies Press. Washington, D.C.

National Research Council of the National Academies (NRC). 2006. Surface temperature reconstructions for the last 2,000 years. National Academy Press, Washington, D.C.

National Research Council of the National Academies (NRC). 2008. Hydrology, ecology, and fishes of the Klamath River basin. National Academies Press. Washington, D.C.

Neave, F. 1943. Diurnal fluctuations in the upstream migration of Coho and spring salmon. Journal of Fisheries Research Board of Canada 6:158-163.

Nei, M. 1987. Molecular evolutionary genetics. Columbia University Press. New York.

Nichols, K., and J. S. Foott. 2005. Health monitoring of juvenile Klamath River Chinook Salmon, FY 2004 Investigational Report. USFWS California-Nevada Fish Health Center, Anderson, CA.

North Coast Regional Water Quality Control Board (NCRWQCB). 2005. Total Maximum Daily Load for Temperature and Implementation Plan, Salmon River, Siskiyou County, California. Accessed at: https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/Salmon_river/062405/part_1_Salmon_temperature_tmdl_report_adopted.pdf

O’Farrell, M., S. Allen-Moran, K. Atkinson, P. Dygert, S. Gallagher, A. Grover, B. Kormos, M. Lacy, E. Larson, M. Mohr, S. Ricker, W. Satterthwaite, and B. Spence. 2015. California coastal Chinook Salmon fishery management: future prospects. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-542

O'Farrell, M. R., M. L. Palmer-Zwahlen, and J. M. Simon. 2010. Is the September 1 river return date approximation appropriate for Klamath River fall Chinook? NOAA-TM-NMFS-SWFSC-468.

Olson, A. 1996. Freshwater rearing strategies of spring Chinook Salmon *(Oncorhynchus tshawytscha*) in Salmon River tributaries, Klamath Basin, California. Master's thesis. Humboldt State University, Arcata, California.

Oregon Department of Fish and Wildlife (ODFW). 2008. A plan for the reintroduction of anadromous fish
in the Upper Klamath Basin. Salem, Oregon.

Oregon Department of Fish and Wildlife (ODFW) and The Klamath Tribes. 2019. Draft Implementation plan for the reintroduction of anadromous fishes into the Oregon portion of the Upper Klamath Basin. 03-01-2019 Draft. Oregon Department of Fish and Wildlife.

Ou, M., T. J. Hamilton, J. Eom, E. M. Lyall, J. Gallup, A. Jiang, J. Lee, D. A. Close, Y. Sang-Seon, C. J. Brauner. 2015. Responses of pink salmon to CO_2-induced aquatic acidification. Nature Climate Change. 2015; 5(10).

Pacific Fishery Management Council (PFMC). 2016. Pacific Coast Salmon Fishery Management Plan for commercial and recreational salmon fisheries off the coasts of Washington, Oregon, and California as amended through Amendment 19. PFMC, Portland, OR.

Pacific Fishery Management Council (PFMC). 2019. Salmon rebuilding plan for Sacramento River fall Chinook draft 12. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon.

Pacific Watershed Associates (PWA). 1994. Action Plan for restoration of the South Fork Trinity River watershed and its fisheries. Prepared for the US Bureau of Reclamation and the Trinity River Task Force. Accessed at: http://www.krisweb.com/biblio/sft_usbor_pwa_1994_sftplan/pwa1.htm

Page, L. M., and B. M. Burr. 1991. A field guide to freshwater fishes: North America north of Mexico. Volume 42 of Peterson field guide series. Houghton Mifflin.

Pearse, D. E. 2016. Saving the spandrels? Adaptive genomic variation in conservation and fisheries management. Journal of Fish Biology 89(6):2697-2716.

Peterson, W.T., J. L. Fisher, C. A. Morgan, S. M. Zeman, B. J. Burke, and K. M. Jacobson. 2018. Ocean ecosystem indicators of salmon marine survival in the northern California Current. https://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/documents/Peterson_etal_2018_revised.pdf.

Platts, W. S., M. A. Shirazi, and D. H. Lewis. 1979. Sediment particle sizes used by salmon for spawning with methods for evaluation. Report EPA 600/3-79-043, U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR.

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(8)e1603198.

Reiser, D. W., and T. C. Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in western North America: Habitat requirements of anadromous salmonids. USDA Forest Service Anadromous Fish Habitat Program, Portland, OR. USDA Forest Service General Technical Report PNW-96. Accessed at: https://www.fs.fed.us/pnw/pubs/journals/pnw_1979_reiser001.pdf

Riddell, B., R. D. Brodeur, A. V. Bugaev, P. Moran, J. Murphy, J. A. Orsi, M. Trudel, L. A. Weitkamp, B. K. Wells, and A. C. Wertheimer. 2018. Ocean ecology of Chinook Salmon. In R.J. Beamish, editor. Ocean Ecology of Pacific salmon and Trout, Chapter 5. American Fisheries Society.

Rupert, D. L., S. A. Gough, N. A. Som, N. J. Davids, W. C. Matilton, A. M. Hill, and J. L. Pabich. 2017. Mainstem Trinity River Chinook Salmon Spawning Survey, 2015 and 2016. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Report Number DS 2017–56, Arcata, California.

Sartori, J. C. 2006. Comparative otolith microstructural analysis of adult, juvenile, and fry life stages of Salmon River spring Chinook salmon of northwestern California. Technical report. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California.

Satterthwaite, W. H., and M.R. O'Farrell. 2018. Inferred ocean distributions of genetically similar Chinook Salmon stocks compared across run timing and river/hatchery of origin. Fisheries Research 199:171-176.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

Shafer, A. B. A., J. B. W. Wolf, P. C. Alves, L. Bergström, M. W. Bruford, I. Brännström, G. Colling, L. Dalén, L. De Meester, R. Ekblom, K. D. Fawcett, S. Fior, M. Hajibabaei, J. A. Hill, A. R. Hoezel, J. Höglund, E. L. Jensen, J. Krause, T. N. Kristensen, M. Krützen, J. K. McKay, A. J. Norman, R. Ogden, E. M. Österling, N. J. Ouborg, J. Piccolo, D. Popović, C. R. Primmer, F. A. Reed, M. Roumet, J. Salmona, T. Schenekar, M. K. Schwartz, G. Segelbacher, H. Senn, J. Thaulow, M. Valtonen, A. Veale, P. Vergeer, N. Vijay, C. Vilà, M. Weissensteiner, L.

Wennerström, C. W. Wheat, and P. Zieliński. 2015. Genomics and the challenging translation into conservation practice. Trends in Ecology and Evolution 30:78–87.

Shaw, T. A., C. Jackson, D. Nehler, and M. Marshall. 1997. Klamath River (Iron Gate Dam to Seiad Creek) life stage periodicities for Chinook, Coho, and steelhead. Prepared by U.S. Fish and Wildlife Service, Coastal California Fish and Wildlife Office, Arcata, California.

Scheiff, A. J., J. S. Lang, and W. D. Pinnix. 2001. Juvenile salmonid monitoring on the mainstem Klamath River at Big Bar and mainstem Trinity River at Willow Creek 1997-2000. Annual report of the Klamath River Fisheries Assessment Program. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California

Shumway, D. L., C. E. Warren, and P. Duodoroff. 1964. Influence of oxygen concentration and water movement on the growth of steelhead trout and Coho Salmon embryos. Transactions of the American Fisheries Society 93(4):342-356.

Snyder, J. O. 1931. Salmon of the Klamath River, California. Division of Fish and Game of California, Sacramento. Fish Bulletin No. 34.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook Salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325-333.

Soto, T., M. Hentz, and W. Harling. 2008. Mid-Klamath Subbasin Fisheries Resources Recovery Plan. Final Draft. USFWS, Yreka, CA. Original 2003. Updated 2008.

Stanford, J., W. Duffy, E. Asarian, B. Cluer, P. Detrich, L. Eberle, S. Edmondson, S. Foot, M. Hampton, J. Kann, K. Malone, and P. Moyle. 2011. Conceptual model for restoration of the Klamath River. In L. Thorsteinson, S. VanderKooi, and W. Duffy, eds. 2011. Proceedings of the Klamath Basin Science Conference, Medford, Oregon, February 1-5, 2010: U.S. Geological Survey Open File Report 2011-1196.

Stanley, W. T., and K. E. Shaffer. 1995. Harbor seal (*Phoca vitulina*) predation on seined salmonids in the lower Klamath River, California. Marine Mammal Science 11(3):376-385.

Stearley, R. F., and G. R. Smith. 1993. Phylogeny of the Pacific trouts and salmons (*Oncorhynchus)* and genera of the Family Salmonidae. Transactions of the American Fisheries Society 122(1):1-33.

Steele, C. A., E. C. Anderson, M. W. Ackerman, M. A. Hess, N. R. Campbell, S. R. Narum, and M. R. Campbell. 2013. A validation of parentage-based tagging using hatchery steelhead in the Snake River basin. Canadian Journal of Fisheries and Aquatic Sciences • 24 June 2013 • https://doi.org/10.1139/cjfas-2012-0451

Stillwater Sciences. 2009. Effects of sediment release following dam removal on the aquatic biota of the Klamath River. Technical Report. Prepared by Stillwater Sciences, Arcata, California for State Coastal Conservancy, Oakland, California. Available at: http://www.Reclamation.gov/mp/kbao/kbra/docs/other/Klamath%20Dam%20Removal%20Biological%20Analysis_FINAL.pdf.

Stillwater Sciences. 2018. Salmon River Floodplain Habitat Enhancement and Mine Tailing Remediation Project. Phase 1: Technical Analysis of Opportunities and Constraints. Technical Memorandum prepared for Salmon River Restoration Council. January 2018. Accessed at: http://srrc.org/publications/programs/habitatrestoration/Salmon%20River%20Floodplain%20Enhancement%20Tech%20Memo_Final%202018.pdf

Stocking, R. W., and J. L. Bartholomew. 2004. Assessing links between water quality, river health and ceratomyxosis of salmonids in the Klamath River system. Department of Microbiology, Oregon State University, Corvallis, OR.

Sullivan, C. M., 1989. Juvenile life-history and age composition of mature fall Chinook salmon returning to the Klamath River, 1984-1986. Master's Thesis. Humboldt State University, Arcata, California.

Sullivan, R. M., and J. P. Hileman. 2019. Effects of managed flows on Chinook *Salmon (Oncorhynchus tshawytscha)* in relation to run-timing, fertility, and fluctuations in water temperature and flow volume. California Fish and Game 105(3):132-176; 2019.

Strange, J. S. 2010. Summary of scientific evidence to guide special flow releases to reduce the risk of adult fall Chinook Salmon mass disease mortality in the Lower Klamath River. Yurok Tribal Fisheries Program. Klamath, CA.

Strange, J. S. 2012. Migration strategies of adult Chinook Salmon runs in response to diverse environmental conditions in the Klamath River basin, Transactions of the American Fisheries Society 141(6)1622-1636.

Suckley, G. 1861. Notices of certain new species of North American Salmonidae from the north-west coast of America. Annals of the Lyceum of Natural History (New York) 7:306-313.

SWRCB (California State Water Resources Control Board). 2018. Draft Environmental Impact Report for the Lower Klamath Project License Surrender Volume I. State Clearinghouse No. 2016122047. Prepared by Stillwater Sciences, Berkeley, CA.

Thom, B. 2020. Letter to Phil Anderson, Chair, Pacific Fishery Management Council. Supplemental NMFS Report 1. March 2020.

Thomas, A. E., J. L. Banks, and D. C. Greenland. 1969. Effect of yolk sac absorption on the swimming ability of fall Chinook Salmon. Transactions of the American Fisheries Society. 1968(3):406-410.

Thomas, V. G. 1985. Experimentally determined impacts of a small, suction gold dredge on a Montana stream. North American Journal of Fisheries Management 5:480-488.

Thomas, W., R. E. Withler, and A. T. Beckenbach. 1986. Mitochondria! DNA analysis of Pacific salmonid evolution. Canadian Journal of Zoology 64:1058-1064.

Thompson, N. F., E. C. Anderson, A. J. Clemento, M. A. Campbell, D. E. Pearse, J. W. Hearsey, A. P. Kinziger, and J. C. Garza. 2020. A complex phenotype in salmon controlled by a simple change in migratory timing. Science 370: 609–613.

Thompson, T. Q., M. R. Bellinger, S. M. O'Rourke, D. J. Prince, A. E. Stevenson, A. T. Rodrigues, M. R. Sloat, C. F. Speller, D. Y. Yang, V. L. Butler, M. A. Banks, and M. R. Miller. 2019. Anthropogenic habitat alteration leads to rapid loss of adaptive variation and restoration potential in wild Salmon populations. Proceedings of the National Academy of Science 116(1):177-186.

Thorsteinson, L., S. VanderKooi, and W. Duffy, editors. 2011. Proceedings of the Klamath Basin Science Conference, Medford, Oregon, February 1–5, 2010: U.S. Geological Survey Open-File Report 2011-1196.

Torgersen, C. E., D. M. Price, H. W. Li, and B. A. McIntosh. 1999. Multiscale thermal refugia and stream habitat associations of Chinook Salmon in northeastern Oregon. Ecological Applications 9(1):301-319.

Troxel, D. 2018. 2018 spring Chinook Salmon creel survey on the Lower Klamath River. California Department of Fish and Wildlife. Northern Region. Klamath River Project.

U.S. Department of Interior (USDI). 2000. Record of decision, Trinity River mainstem fishery restoration final environmental impact statement/environmental impact report. U.S. Department of Interior, Washington D.C.

U.S. Department of Interior (USDI). 2012. Klamath Facilities Removal Final Environmental Impact Statement/Environmental Impact Report. United States Department of Interior.

U.S. Fish and Wildlife Service (USFWS) and Hoopa Valley Tribe. 1999. Trinity River Flow Evaluation. Final Report. A report to the Secretary of the Interior. Accessed at: https://www.trrp.net/library/document/?id=226

U.S. Fish and Wildlife Service (USFWS). 2000. Record of Decision, Trinity River Mainstem Fishery Restoration, Final Environmental Impact Statement/Environmental Impact Report, U.S. Department of the Interior, Washington, DC. Accessed at: https://www.trrp.net/library/document/?id=227

U.S. Fish and Wildlife Service (USFWS). 2003. Klamath River fish die-off September 2002: Causative factors of mortality. Report Number AFWO-F-02-03. November 7, 2003.

U.S. Fish and Wildlife Service and California Department of Fish and Game (USFWS/CDFG). 1956. A Plan for the Protection and Maintenance of Fish and Wildlife Resources Affected by the Trinity River Division, Central Valley Project. Prepared jointly by United States Fish and Wildlife Service and the California Department of Fish and Game. November 1956.

U.S. Forest Service (USFS). 1996. Fish theme name: "Fish Species Range" (knf_fish). Survey data courtesy of USDA Forest Service, Klamath National Forest, KNF Supervisor's Office, Yreka, California. Data downloaded on August 24, 2005. As cited in Carter, K., and S. Kirk. 2008. Fish and fishery resources of the Klamath River basin. 2008. Appendix 5 *in* North Coast Regional Water Quality Control Board. 2010. Final staff report for the Klamath River Total Maximum Daily Loads (TMDLs) addressing temperature, dissolved oxygen, nutrient, and microcystin impairments in California. The proposed site-specific dissolved oxygen objectives for the Klamath River in California and the Klamath River and Lost River Implementation plans. California Water Boards, North Coast Region, Santa Rosa, CA. Accessed at: https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/klamath_river/

U.S. Forest Service (USFS). 2006. Review comments, Klamath TMDL ReportFish Population distribution map. Letter dated July 7, 2006. Klamath National Forest, 2 pp. As cited in Carter, K., and S. Kirk. 2008. Fish and fishery resources of the Klamath River basin. 2008. Appendix 5 *in* North Coast Regional Water Quality Control Board. 2010. Final staff report for the Klamath River Total Maximum Daily Loads (TMDLs) addressing temperature, dissolved oxygen, nutrient, and microcystin impairments in California. The proposed site-specific dissolved oxygen objectives for the Klamath River in California and the Klamath River and Lost River Implementation plans. California Water Boards, North Coast Region, Santa Rosa, CA. Accessed at: https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/klamath_river/

U.S. Global Change Research Program (USGCRP). 2009. T. R. Karl, J. M. Melillo, and T. C. Peterson, editors. Global Climate Change Impacts in the United States. Cambridge University Press.

U.S. Global Change Research Program (USGCRP). 2017. Wuebbles, D. J., D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, and T. K. Maycock, editors. Climate Science Special

Report: Fourth National Climate Assessment, Volume I U.S. Global Change Research Program, Washington, DC, USA,

Upton, H. F. 2010. Commercial fishery disaster assistance. Congressional Research Service. RL34209.

Walbaum, J. J. 1792. Petri Artedi renovati: bibliotheca Vet philosophia ichlhyologica. Ichthyologiae, pars III. A. F. Roese, Grypeswaldiae.

Wales, J. H. 1951. “The decline of the Shasta River king salmon run.” California Department of Fish and Game.

Waples, R. S. 1991a. Pacific salmon, *Oncorhynchus* spp., and the definition of “species” under the endangered species act. Marine Fisheries Review 53**:**11–22.

Waples, R. S. 1991b. Genetic interactions Between Hatchery and Wild Salmonids: Lessons from the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences. 48:124-133.

Waples R. S. 1995. Evolutionarily significant units and the conservation of biological diversity under the Endangered Species Act. Pages 8—27 in J.L. Nielsen and G.A. Powers, editors. Evolution and the aquatic ecosystem: Defining unique units in population conservation. Symposium 17. American Fisheries Society, Bethesda, Maryland.

Waples, R. S. 1999. Dispelling some myths about hatcheries. Fisheries 24(2):12–21

Waples, R. S. 2006. Distinct population segments. Pages 127–149 in J. M. Scott, D.D. Goble, and F. W. Davis. The Endangered Species Act at thirty: Conserving biodiversity in human-dominated landscapes. Island Press, Washington, DC.

Waples, R. S., and S. T. Lindley. 2018. Genomics and conservation units: The genetic basis of adult migration timing in Pacific salmonids. Evolutionary Applications 11:1518-1526.

Waples, R. S., K. A. Naish, and C. R. Primmer. 2020. Conservation and Management of salmon in the age of genomics. Annu. Rev. Anim. Biosci. 8:117–143.

Waples, R. S., D. J. Teel, J. M. Myers, and A. R. Marshall. 2004. Life-history divergence in Chinook Salmon: historic contingency and parallel evolution. Evolution 58:386-403.

Wedemeyer, Gary A. [Ed] 2001. Fish hatchery management, second edition. American Fisheries Society, Bethesda MD, 733 pp.

Wells, B. K., J. A. Santora, J. C. Field, R. B. MacFarlane, B. B. Marinovic, W. J. Sydeman. 2012. Population dynamics of Chinook salmon *Oncorhynchus tshawytscha* relative to prey availability in the central California coastal region. Mar Ecol Prog Ser. 457:125–37. https://doi.org/10.3354/meps09727

West, J. R. 1991. A proposed strategy to recover endemic spring-run Chinook Salmon populations and their habitats in the Klamath River Basin. USDA-Forest Service. Klamath National Forest.

Williams, J. G. 2006. Central Valley salmon: a perspective on Chinook and steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science 4(3).

Williams, T. H., S. T. Lindley, B. C. Spence, D. A. Boughton. 2011. Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act: Southwest. 20 May 2011 – Update to 5 January 2011 report. National Marine Fisheries Service, Southwest Fisheries Science Center, Fisheries Ecology Division,110 Shaffer Road, Santa Cruz, California 95060

Williams, T. H., J. C. Garza, N. J. Hetrick, S. T. Lindley, M. S. Mohr, J. M. Myers, M. R. O'Farrell, R. M. Quinones, and D. J. Teel. 2013. Upper Klamath and Trinity River Chinook Salmon Biological Review Team Report. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-502.

Williamson, K., and D. Hillemeier. 2001. An assessment of pinniped predation upon fall-run Chinook Salmon in the Klamath River Estuary, CA, 1998. Yurok Tribal Fisheries Program. Klamath, CA. Accessed at: http://www.yuroktribe.org/departments/fisheries/documents/98Finalbwpin_pred_WILLIAMSON.pdf

Wydoski, R. S., and R. R. Whitney. 1979. Inland fishes of Washington. University of Washington Press. Seattle, Washington.

Appendices

Appendix A. California Hatchery Scientific Review Group Recommendations for Trinity River and Iron Gate Hatchery Chinook Salmon Artificial Propagation Programs

Following are the recommendations of the CA HSRG (2012) for Trinity River Hatchery Chinook Salmon programs. Some, but not all, of these recommendations have been implemented.

Recommendations for all Trinity River Hatchery Programs:

a) Natural-origin fish should be incorporated into broodstock at a minimum rate of 10% to prevent divergence of the hatchery and natural components of the integrated population.
b) Adult holding facilities should be upgraded/expanded to provide adequate space, water flows and temperatures to hold the number of adults required for broodstock at high rates of survival (more than 90%). Facilities need to be adequate to hold the expected number of unripe adults for extended periods with minimal hatchery-caused mortality.
c) The adult spawning facility is inadequate to meet current needs for fish sorting, spawning and monitoring and should be upgraded.
d) Investigate the feasibility of collecting natural-origin adult fish at alternate locations. The existing trapping location is very limited in its ability to capture fish representing the entire spectrum of life-history diversity. Only fish that migrate to the furthest upstream reaches are susceptible to capture.
e) Performance standards for each phase of the fish culture process should be established and tracked annually. Summaries of data collected with comparisons to established targets must be included in annual hatchery reports.
f) A Monitoring and Evaluation Program should be developed and implemented, and a Hatchery Coordination Team formed for the program.
g) Co-managers should develop and promulgate a formal, written fish health policy for the operation of the hatchery. Hatchery compliance with this policy should be documented annually as part of a Fish Health Management Plan. The current fish health policy is inadequate to protect native stocks.
h) Co-managers should develop an updated Hatchery Procedure Manual that includes performance criteria and culture techniques described in IHOT (1995), Fish Hatchery Management (Wedemeyer 2001), or comparable publications. The fish culture manual in current use (Leitritz and Lewis 1976) is outdated and does not reflect current research and advancements in fish culture.
i) Adult collection facilities should be operated throughout the entire temporal migration period of the run and should not exclude fish with particular life history characteristics, except when non-representative broodstock collection is necessary to achieve program goals. Currently, the trap is shut down for a period of approximately two weeks to

minimize hybridization between separate spring and fall Chinook Salmon. Fish collected during this period should be euthanized without spawning.

j) Tag analysis should be used to determine the number of spring and fall Chinook Salmon spawned during the suspected period of run overlap (e.g., fish spawned in the last two weeks of spring and the first two weeks of fall). Tags should be read and egg lots tracked and eliminated from production as appropriate to reduce introgression of the two runs. Incubation techniques should therefore allow for separation of eggs from individual parents/families (no more than two families per tray).

k) Program fish should be 100% coded-wire tagged and 25% adipose fin-clipped (as suggested in other sections of CA HSRG (2012)). Yearling releases should receive an additional distinguishing external mark or tag (e.g., a ventral fin clip) allowing real-time discrimination from fingerling releases at the adult stage.

l) Returning yearling-program origin adults should not be used as broodstock. If eggs are collected from or fertilized by such fish, they should be culled soon after spawning. Adequate numbers of fingerlings should be released each year to meet numerical goals for broodstock. When adult returns from fingerling releases are inadequate to satisfy hatchery egg take needs, yearling returns may be used to make up this deficit.

m) CWT releases and recoveries of fall Chinook should be reported annually to RMIS in a timely manner.

n) Jacks should be incorporated into the broodstock at a rate that does not exceed 50% of the total number of jacks encountered during spawning operations and in no case more than 5% of the total males spawned.

o) Fish growth trajectories need to be monitored more closely to achieve the identified release target of 90 fpp for fingerlings and 10 fpp for yearlings. Data supplied by the hatchery indicate that average release size for the two respective groups has been 108 fpp and 15.4 fpp from 2000 – 2010.

Major Program Recommendations Specific to the Trinity River Hatchery Fall Chinook Salmon Program:

a) Adult collection facilities should be operated throughout the entire temporal migration period of the run and should not exclude fish with particular life history characteristics, except when non-representative broodstock collection is necessary to achieve program goals. Currently, the trap is shut down for a period of approximately two weeks to minimize hybridization between separate spring and fall Chinook Salmon. Fish collected during this period should be euthanized without spawning.

b) Tag analysis should be used to determine the number of spring and fall Chinook Salmon spawned during the suspected period of run overlap (e.g., fish spawned in the last two weeks of spring spawning and the first two weeks of fall spawning). Tags should be read and egg lots tracked and eliminated from production as appropriate to reduce introgression of the two runs. Incubation techniques should therefore allow for separation of eggs from individual parents/families (no more than two families per tray).

c) Program fish should be 100% coded-wire tagged and 25% adipose fin-clipped. "Yearling" releases should receive an additional distinguishing external mark or tag (e.g., a ventral fin clip) allowing real-time discrimination from fingerling releases at the adult stage.

d) Returning yearling-origin adults should not be used as broodstock. If eggs are collected from or fertilized by such fish, they should be culled soon after spawning. Adequate numbers of fingerlings should be released each year to meet numerical goals for broodstock. When adult returns from fingerling releases are inadequate to satisfy hatchery egg take needs, yearling returns may be used to make up this deficit.

e) CWT releases and recoveries of fall Chinook Salmon should be reported annually to RMIS in a timely manner.

f) Jacks should be incorporated into the broodstock at a rate that does not exceed 50% of the total number of jacks encountered during spawning operations and in no case more than 5% of the total males spawned.

g) Fish growth trajectories need to be monitored more closely to achieve the identified release target of 90 fpp for fingerlings and 10 fpp for yearlings. Data supplied by the hatchery indicate that average release size for the two respective groups has been 108 fpp and 15.4 fpp from 2000 – 2010.

Major Program Recommendations Specific to the Trinity River Hatchery Spring Chinook Salmon Program:

a) Adult collection facilities should be operated throughout the entire time period of the migration and should not exclude fish with particular life history characteristics, except when non-representative broodstock collection is necessary to achieve program goals. Currently, the trap is shut down for a period of approximately two weeks to minimize hybridization between separate spring and fall Chinook Salmon. Fish collected during this period should be euthanized without spawning.

b) Tag analysis should be used to determine the number of spring and fall Chinook Salmon spawned during the suspected period of run overlap (e.g., fish spawned in the last two weeks of spring and the first two weeks of fall). Tags should be read and egg lots tracked and eliminated from production as appropriate to reduce introgression of the two runs. Incubation techniques should therefore allow for separation of eggs from individual parents/families (no more than two families per tray).

c) Program fish should be 100% coded wire tagged and 25% adipose fin-clipped. "Yearling" releases should receive an additional distinguishing external mark or tag (e.g., a ventral fin clip) allowing real-time discrimination from fingerling releases at the adult stage.

d) Returning yearling-origin adults should not be used as broodstock. If eggs are collected from or fertilized by such fish, they should be culled soon after spawning. Adequate numbers of fingerlings should be released each year to meet numerical goals for broodstock. When adult returns from fingerling releases are inadequate to satisfy hatchery egg take needs, yearling returns may be used to make up this deficit.

e) CWT releases and recoveries of spring (and fall) Chinook Salmon should be reported annually to RMIS in a timely manner.
f) Jacks should be incorporated into the broodstock at a rate that does not exceed 50% of the total number of jacks encountered during spawning operations and in no case more than 5% of the total males spawned.
g) Fish growth trajectories need to be monitored more closely to achieve the identified release target of 90 fpp for fingerlings and 10 fpp for yearlings.

Following are the recommendations of the CA HSRG (2012) for Iron Gate Hatchery Chinook Salmon programs. Some, but not all, of these recommendations have been implemented. If the Dam Removal project on the Klamath River goes into effect, IGH will no longer be functional resulting in many of the following recommendations becoming irrelevant.

Recommendations for all Iron Gate Hatchery Programs:

a) Clear goals should be established for the program. Program production goals should be expressed in terms of the number of age-3 ocean recruits just prior to harvest (Chinook Salmon), age-3 adults returning to freshwater (Coho Salmon), and the number of adults and half-pounders returning to freshwater (steelhead).
b) Adult holding facilities in hatcheries should be upgraded/expanded to provide adequate space, water flows and temperature regimes to hold the number of adults required for broodstock at high rates of survival (greater than 90%). Facilities need to be adequate to hold the expected number of unripe adults for extended periods with minimal hatchery-caused mortality.
c) The adult spawning facility is inadequate to meet current needs for fish sorting, spawning and monitoring and should be upgraded.
d) All outdoor raceways should be protected from predators with bird netting or similar protection to reduce predation rates on juvenile fish.
e) Managers should investigate the feasibility of collecting natural-origin adult fish at alternate locations. The existing trapping location is very limited in its ability to capture fish representing the entire spectrum of life history diversity. Only fish that migrate to the furthest upstream reaches are susceptible to capture.
f) Performance standards for each phase of the fish culture process should be established and tracked annually. Summaries of data collected with comparisons to established targets must be included in annual hatchery reports.
g) CDFG should develop and promulgate a formal, written fish health policy for operation of its anadromous hatcheries through the Fish and Game Commission policy review process. Hatchery compliance with this policy should be documented annually as part of a Fish Health Management Plan. The current CDFG fish health policy is inadequate to protect native stocks.

h) CDFG should develop an updated Hatchery Procedure Manual which includes performance criteria and culture techniques presented in IHOT (1995), Fish Hatchery Management (Wedemeyer 2001) or comparable publications. The fish culture manual (Leitritz and Lewis 1976) is outdated and does not reflect current research and advancements in fish culture.
i) A Monitoring and Evaluation Program should be developed and implemented and a Hatchery Coordination Team formed for the program. Implementation of these processes will inform hatchery decisions and document compliance with best management practices defined in this report.

Major Program Recommendations Specific to the Iron Gate Hatchery Fall Chinook Salmon Program:

a) Managers should consider changes in the program, including reducing the size of the program, to mitigate disease issues. Large numbers of naturally spawning fish may increase the incidence of *C. shasta* disease through the release of myxospores from carcasses, which in turn increases the probability of perpetuating myxozoan infections in juvenile Chinook Salmon and Coho Salmon in the following spring and summer. We note that in any situation where program size is reduced or programs eliminated, in no case should such change result in relinquishment of mitigation responsibility.
b) Natural-origin fish should be incorporated into broodstock at a minimum rate of 10% to prevent divergence of the hatchery and natural components of the integrated population. This may require auxiliary adult collection facilities (e.g., Bogus Creek) or alternative collection methods (e.g., seining or trapping).
c) Jacks should be incorporated into the broodstock at a rate that does not exceed 50% of the total number of jacks encountered during spawning operations and in no case more than 5% of the total males spawned.
d) Program fish should be 100% coded-wire tagged and 25% adipose fin-clipped. "Yearling" releases should receive an additional distinguishing external mark or tag (e.g., a ventral fin clip) allowing real-time discrimination from fingerling releases at the adult stage. Returning yearling-origin adults should not be used as broodstock. If eggs are collected from or fertilized by such fish, they should be culled soon after spawning. Adequate numbers of fingerlings should be released each year to meet numerical goals for broodstock. When adult returns from fingerling releases are inadequate to satisfy hatchery egg take needs, yearling returns may be used to make up this deficit.
e) CWT releases and recoveries of fall Chinook Salmon should be reported annually to RMIS in a timely manner.
f) Water quality for egg incubation should be improved to remove organic debris and siltation that is likely affecting egg survival. If the air incubation solution tried in 2011 is ineffective, hatchery and fish health staff should continue studies to determine the cause of low egg survival rates.

Appendix B. Methods Used to Evaluate Ocean Fishery Harvest

The department evaluated ocean fishery harvest using marked and tagged TRH hatchery-origin UKTR spring Chinook Salmon as a surrogate for all UKTR Spring Chinook Salmon. Individual CWT codes were identified as UKTR spring Chinook Salmon using the species, run type, and hatchery location. Recoveries were expanded for the proportion of total released fish with CWTs and adipose fin-clips and sample rate (the proportion of the fishery by time and area that was observed). Results were summarized by ocean salmon fishery management area as described in the Pacific Fishery Management Council's Salmon Fishery Management Plan (FMP).

Because of inconsistent, and in some cases low, interannual CWT tag and mark rates, UKTR spring Chinook Salmon recoveries prior to brood year 1995 were excluded from the analysis of fishery harvest, as were incomplete broods (i.e., 2013-2015). These exclusions left 1,596 recoveries available to evaluate ocean salmon fishery harvest by fishery type (i.e., commercial or recreational), time of year (monthly time-steps) and geographic location (i.e., FMP management area). These recoveries were available to ocean salmon fisheries from 1997 (brood year 1995 age-2) through 2017 (brood year 2012 age-5). No UKTR spring Chinook Salmon younger than age-2 or older than age-5 were encountered from these broods[18].

To conduct this analysis, CWTs are extracted and decoded in a laboratory, merged with data from ocean salmon harvest and fishing effort, including the proportion of the fishery that was observed, and are made publicly available through the Regional Mark Information System (www.rmpc.org). These fishery recoveries combined with hatchery release information, including the proportion of released fish marked with an adipose fin-clip and tagged with CWTs, can be used to estimate total harvest of a particular stock at various levels of temporal and geographic stratification and by fishery type. While Genetic Stock Identification (GSI) can sometimes be used to identify stocks in mixed stock fisheries, standard GSI techniques cannot distinguish UKTR spring Chinook Salmon from UKTR fall Chinook Salmon because they are not genetically distinct. In addition, existing GSI samples are very limited in quantity and in temporal and spatial coverage.

Trinity River Hatchery has released CWT tagged UKTR spring Chinook Salmon annually since at least 1976 (Table 6.14 in report); however, prior to 1995 there is considerable interannual variation in the total number of fish released and the proportion tagged. For example, a little over 35,000 UKTR spring Chinook Salmon were released at a 98% CWT tag rate in 1980 followed by over 1.6 million released at a 17% tag rate the following year. Inconsistent and relatively low tag rates confound fishery harvest analyses, particularly when overall recoveries are few and fishing seasons by design vary between years in time and space to protect vulnerable stocks

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[18] One age-6 UKTR Spring Chinook was encountered in 1988 (brood year 1982) in the Coos Bay commercial ocean salmon fishery.

(i.e., weak-stock management). This variation leads to unreliable results, and likely over- or under-estimation of actual harvest. Since 1995, an average of 1.4 million UKTR spring Chinook Salmon have been released from TRH with an average 23% CWT tag rate, reducing variability in inter-annual comparisons of UKTR spring Chinook Salmon harvest by ocean salmon fisheries (Table 4.1).

To account for varying fishing opportunity and relative abundance of other stocks, and to evaluate the times and areas where hatchery-origin UKTR spring Chinook Salmon were encountered in fisheries, the aggregate number of CWT recoveries expanded for hatchery production and sampling was scaled to the aggregate total harvest of all stocks by management area and month time-step.

Methods Used in Comparison of Hatchery-origin UKTR Spring and Fall Chinook Salmon Harvest Distribution in Ocean Salmon Fisheries

To determine whether management protections for Klamath River fall Chinook Salmon (KRFC; these are primarily UKTR fall Chinook Salmon but may also include a small number of fish from a different ESU; see *Section 6.11.1* for details) might apply to UKTR spring Chinook Salmon, this report compares the ocean spatial distribution of the UKTR spring and fall Chinook Salmon ecotypes[19]. Both ecotypes of the UKTR Chinook Salmon ESU have an annually marked and tagged hatchery component, allowing for differentiation of the ocean distribution of spring and fall TRH hatchery fish using tag recoveries in ocean salmon fisheries. Because fishery harvest is commonly used to evaluate ocean distribution of both natural and hatchery-origin salmon, the Department's analysis assumes that ocean harvest can be used as a proxy for ocean spatial distribution of both natural- and hatchery-origin fish. While this underlying assumption cannot be validated directly due to lack of fishery-independent data, fishery harvest is commonly used to evaluate probable ocean distribution of both natural- and hatchery-origin salmon. Also, inference of spatial patterns based on fishery interactions may in some cases be preferred from a management perspective over true spatial distribution. Because management actions are taken at the stock complex level, UKTR fall Chinook Salmon hatchery CWTs from both Iron Gate and Trinity River Hatcheries were used in this analysis. Data necessary to evaluate fishery impacts on natural-origin UKTR spring Chinook Salmon are currently unavailable due to lack of age-structured spawning return composition and cohort reconstructions. To ensure comparable metrics, only hatchery-origin UKTR fall Chinook Salmon (KRFC) were used for this comparison to UKTR spring Chinook Salmon ocean distribution and relative contribution.

Coded-wire tag and associated catch-sample and hatchery release information was downloaded from the Regional Mark Processing Center (www.rmpc.org) for brood years 1995 – 2012. In the commercial ocean salmon fishery 7,498 individual UKTR fall Chinook Salmon (KRFC)

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[19] See Section 7.4.6 for conclusions concerning protection afforded by existing regulations.

CWT recoveries and 1,596 TRH UKTR spring Chinook Salmon CWTs were used in this analysis. In the recreational ocean salmon fishery 1,547 UKTR fall Chinook Salmon (KRFC) CWTs and 297 TRH UKTR spring Chinook Salmon CWTs were used. Some open time-area-fisheries in the region over the period in this study had very few CWT recoveries, or none, from the 18 broods, while other time-area combinations are no longer available to ocean salmon fisheries because of regulation changes. For example, commercial ocean salmon fisheries south of Point Arena are currently closed in April to protect ESA Endangered Sacramento River winter Chinook Salmon, among others. Despite uncertainties introduced by low numbers of recoveries, all time-area combinations were retained in the analysis except recoveries north of Cape Falcon, Oregon (not shown). Recoveries north of this ocean salmon management boundary were excluded from the analysis due to the inability to apply management actions north of that location through state or federal regulatory mechanisms. The number of recreational ocean salmon fishery CWTs recovered from these stocks is generally low, especially in certain times and locations. Results based on times and areas with few recoveries should be interpreted with caution because no harvest of the stock was observed in most years within the analysis, and some seemingly higher levels of harvest may be influenced by a single or few years of sample data.

Each individual CWT recovery was expanded for its associated proportion of hatchery released Chinook that contained a CWT and the proportion of the fishery that was sampled, representing the hatchery component of UKTR fall Chinook Salmon (KRFC) and UKTR spring Chinook Salmon harvest in ocean salmon fisheries. The CWT harvest was then aggregated by stock, management area, and month time-step across all 18 broods.

While variation in total cumulative harvest could indicate variation in total harvest among times and areas, the results are complicated by total all-stocks harvest in that time-area and by interannual variation in fishing opportunity and fishing effort throughout the time period within a given time-area-fishery. For example, the commercial harvest of TRH UKTR spring Chinook Salmon is equally split between Oregon and California fisheries (see *Section 6 Factors Affecting the Ability to Survive and Reproduce*). However, the total all-stocks harvest is significantly higher in California and seasonal regulations between the states are inconsistent both between years and between management areas. UKTR fall Chinook Salmon (KRFC) and/or TRH UKTR spring Chinook Salmon from brood year 1995 would first be encountered in ocean salmon fisheries as age-2 fish in 1997, while these stocks would last be encountered as age-5 fish in 2000; however, very few age 5+ UKTR fall Chinook Salmon (KRFC) or TRH UKTR spring Chinook Salmon have been observed in ocean fisheries.

Fishing effort by fishery, management area and month is annually reported in the Review of Ocean Salmon Fisheries (www.pcouncil.org; Appendix A), and was summed across the 1997 through 2017 harvest years and intended to capture all age classes within the 1995 through 2012 brood years. Fish caught in the Oregon ocean waters commercial fishery, but ultimately landed in California prior to the practice's prohibition in 2005, was attributed to Oregon. Some Oregon state-water only commercial fisheries occur in December but are not shown; no UKTR fall Chinook Salmon (KRFC) or TRH UKTR spring Chinook Salmon have been observed in that fishery. Likewise, some recreational fisheries occurred in February in California but are not shown because no UKTR fall Chinook Salmon (KRFC) or TRH UKTR spring Chinook Salmon were harvested. Additionally, Coho salmon-only fishing effort (Oregon only) that could be determined was excluded for both commercial and recreational fisheries.

To account for variable fishing opportunity and resulting total fishing effort (i.e., the number of days fished), the catch per unit effort was determined by stock, fishery type, management area, and month. Again, this comparison might indicate variation in total harvest among times and areas; however, the relative abundance of the two ecotypes may not be directly comparable due to higher hatchery production of UKTR fall Chinook Salmon (both IGH and TRH origin). On average over 8.8 million UKTR fall Chinook Salmon are released from Iron Gate and Trinity River hatcheries (brood years 1995-2012), whereas 1.4 million UKTR spring Chinook Salmon are released annually from Trinity River Hatchery only. Lower abundance of UKTR spring Chinook Salmon hatchery stock could reasonably be expected to result in lower total harvest of that stock, and differences in harvest per day fished between the UKTR spring and fall Chinook Salmon ecotypes may not serve as an appropriate indicator of stock distribution.

To account for differences in overall hatchery abundance (as measured by total hatchery releases), the harvest per day fished (i.e., catch per unit effort or CPUE) was further scaled to the number of hatchery fish released by stock. This computation gives an index of ocean harvest per fishing effort per released Chinook Salmon (e.g., Satterthwaite and O'Farrell 2018, PFMC 2019, Lindley et al. 2009). Specifically, the Department analysis evaluated the expanded CWT recoveries per 100 days fished (commercial; 1,000 days fished for recreational) per 1 million released smolts.

Appendix C. General Form of Harvest Control Rules for Klamath and Sacramento River Fall Chinook Salmon Fishery Management

Figure 1 displays the form of harvest control rule used for both UKTR fall Chinook Salmon Sacramento River (SR) fall Chinook Salmon. The exploitation rate (F) is listed on the Y-axis and the pre-fishery ocean abundance in spawner equivalent units (N) is listed on the X-axis. Break points in the curve along the X-axis are calculated using biological concepts such as the Minimum Stock Size Threshold (MSST), the spawner escapement level expected to produce the maximum sustainable yield (S_{MSY}), and exploitation rate for acceptable biological catch (F_{ABC}). Break points are calculated as follows:

$A = MSST / 2$
$B = (MSST + S_{MSY}) / 2$
$C = S_{MSY} / (1 - 0.25)$
$D = S_{MSY} / (1 - F_{ABC})$

Along the Y-axis, the control rule sets a maximum fishery exploitation rate at F_{ABC}, which is the Maximum Fishery Mortality Threshold slightly reduced to allow for scientific uncertainty in abundance estimation methods. Exploitation rates decrease steadily with declining abundance forecast until two levels of *de minimis* fishery exploitation rates are reached at F = 0.25 and F = 0.10.

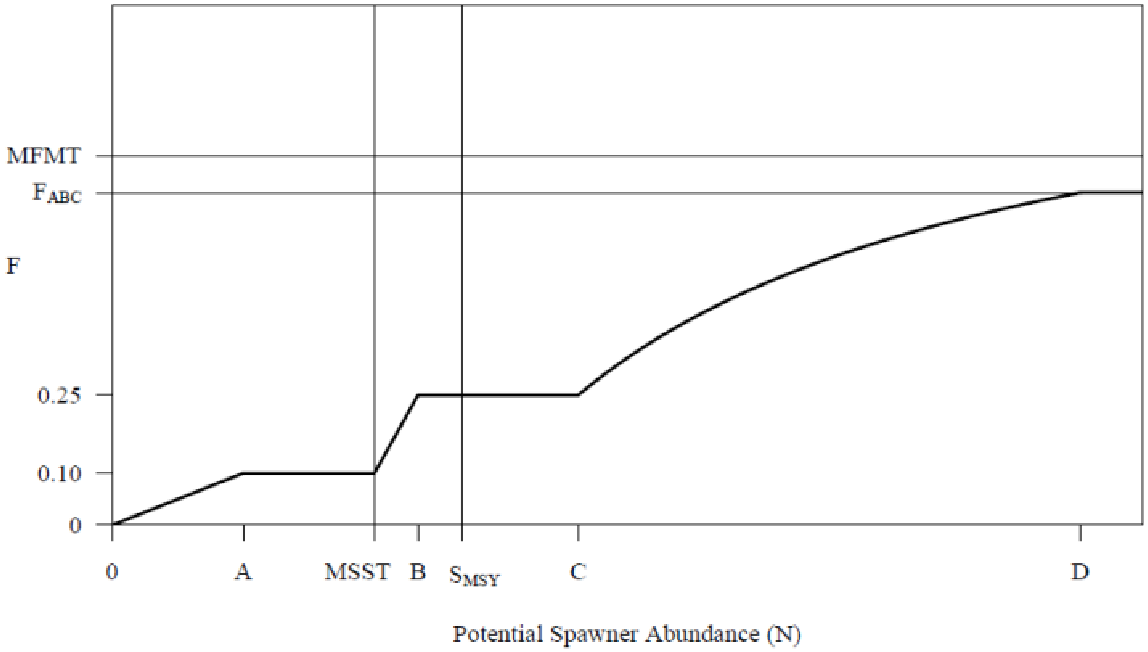

Figure 1. Control rule for UKTR fall Chinook Salmon and Sacramento River fall Chinook Salmon. Abundance is pre-fishery ocean abundance in spawner equivalent units, and F is the exploitation rate. Reference points in the control rule defined in the text.

Appendix D. Summary of Ford et al. (2020): Reviewing and Synthesizing the State of the Science Regarding Associations between Adult Run Timing and Specific Genotypes in Chinook Salmon and Steelhead: Report of a workshop held in Seattle, Washington, 27–28 February 2020

Given the multitude of recently completed and active genetic studies investigating specific genomic associations with run timing in salmonids, and their potential conservation and Endangered Species Act listing implications, NOAA Fisheries Northwest Fisheries Science Center convened a panel of fisheries geneticists in February 2020 to discuss the current state of the science and to identify areas of agreement, areas of uncertainty, conservation implications, and future research needs. The workshop was attended by federal, state, and academic geneticists and conservation planners. The proceedings became publicly available in June 2020 (Ford et al. 2020).

This appendix summarizes the main points presented in Ford et al. (2020). Many of these points refer to highly technical genetic and genomic research results and conclusions. These are reproduced and summarized here for reference in this California Endangered Species Act status review. Readers who require more information should refer to the original report referenced below.

Current State of Research

Summarizing the findings and recommendations presented in Ford et al. (2020), it is apparent that deconvoluting the genetic and genomic basis of run-timing is complex. It is generally accepted that run timing phenotypic variation is strongly correlated with genetic sequence variation in a relatively small (~200 Kb) region of the *GREB1L/ROCK1* region of chromosome 28 in Chinook Salmon and steelhead. Run-timing variation is also affected to a lesser degree by effects of other genes and environmental factors.

There are two alleles in this region: an “early migrating” allele (E) and a “late migrating” allele (L). Fish with homozygous genotypes, EE and LL, exhibit early and late return timing, respectively. Heterozygotes (EL) generally exhibit an intermediate return timing, though, depending on the population, return can be skewed either early or late. The extent and importance of heterozygotes that possess both early and late arriving alleles is an active topic of debate. Results have been confounded by inconsistencies in sampling strategies between studies and effects due to habitat alteration over several decades.

It is unknown how genetic variation in the *GREB1L/ROCK1* region actually causes variations in life history strategy – all of the studies to date have successfully established correlations, but not the actual biochemical pathways by which such variation functions in individual fish. Applying the current state of knowledge to conservation decisions is also a subject of debate. There were a few areas of agreement and many areas of disagreement – the issue is far from settled. A key conservation point where participants were in agreement is that conservation units should continue to be defined by patterns of genetic diversity across the genome (e.g.

microsatellite and SNP loci), not by variation in small genomic regions correlated with specific traits of interest, such as run-timing.

Areas of Agreement and Uncertainty

The following are verbatim points of agreement and uncertainty listed in Ford et al. (2020). The authors note that they did not attempt to come to consensus on these points. Rather, these were statements generally agreed upon by the meeting participants. Readers should refer to the original report for expanded discussions of each point below.

Is the GREB1L/ROCK1 region responsible for adult migration timing, and if so by what mechanism?

Areas of agreement:

1. A single region in the genome has a strong statistical association with adult run timing.
2. The migration phenotype measured across prior studies is not standardized, and efforts should be made to do so.
3. Marker development, validation, and standardization is extremely important.

Areas of uncertainty:

1. The causal variant(s) for adult run timing remain to be identified.

What is the distribution of genetic variation for adult migration timing in space and time? Do the genes associated with migration timing have the same effect in populations inhabiting different environments and with different genetic backgrounds?

Areas of agreement:

1. The GREB1L/ROCK1 association with run timing is best characterized in US West coastal populations for both Chinook salmon and steelhead, and to some degree in the Columbia River basin.

Areas of uncertainty:

1. Our current understanding of both the contemporary and historical distribution of genetic variation in GREB1L/ROCK1, in association with run timing, is confounded by issues with phenotyping, influence of hatchery populations, and anthropogenic activities influencing access to habitat across space and time.

What is the pattern of dominance among haplotypes in the GREB1L/ROCK1 genomic region? What phenotype do heterozygotes express, and what is their fitness compared to homozygotes?

Areas of agreement:

1. Heterozygotes are likely an important mechanism for the spread and maintenance of the early migration alleles over long time scales.

Areas of uncertainty:

1. It may be too simplistic to focus on dominance of migration timing alone since genetic variation at the GREB1L/ROCK1 region also could influence other traits that are more difficult to study.

In what circumstances is it reasonable to conclude that the current distribution of GREB1L genes accurately reflects historical (pre-European contact) patterns? When/where is that not a good assumption?

Areas of agreement:

1. Interaction between individuals with variable run timing has occurred historically, is expected, and likely varies depending on historical environmental conditions. However, anthropogenic impacts have also likely changed these interactions in many locations.

Areas of uncertainty:

1. It is unclear how much demographic isolation from fall run is required for spring Chinook salmon to persist.

How common are large-effect genes? Is it likely that strong associations will be found between specific alleles and many other phenotypic/life-history traits in salmon?

Areas of agreement:

1. Loci of large effect have been identified for other salmonid life-history traits.

Areas of uncertainty:

1. More data are needed from whole genome sequencing to know the extent to which complex traits are controlled by single genes of large effect, or many loci of smaller effect and how this various among populations.

Prince et al. (2017) concluded that the haplotypes associated with early migration timing evolved only once within each species. Is that the case, or are the genetic variants more evolutionarily labile?

Areas of agreement:

1. 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 that have been well characterized evolved long ago in each species' evolutionary history. It is also clear, based on available data, that the allelic variants for early migration have not arisen independently via new mutations from the genomic background of late migration individuals in each watershed.

Needed Future Research

The participants outlined the following areas for future research:

1. Better standardization and characterization of adult migration phenotypes in multiple populations and lineages, including when the 'decision' to migrate is made, how it relates to the timing of sexual maturity and the relationship(s) between the date of freshwater entry and subsequent upstream movements.
2. More thorough marker development and validation (see next section). Ideally, identification of the functional variant(s) in the GREB1L/ROCK1 region that cause alternative migration phenotypes.
3. Greater understanding of the physiological mechanisms leading to alternative migration phenotypes.
4. Tests for association of GREB1L/ROCK1 variation on phenotypes other than adult run timing, such as timing of sexual maturity or other life-history traits.
5. More thorough evaluations of the genetics of run timing variation, throughout the geographic range of Chinook salmon and steelhead, as well as studies in other salmon species in order to develop broad baseline data on the historical and current distribution of alleles at this locus. Current studies have been primarily focused on a limited number of West Coast and Columbia River populations. These investigations should include characterization of the full suite of genetic variants (and their effect sizes) contributing to run timing,
6. More thorough characterization of GRE1L/ROCK1 haplotype diversity and the phenotype and dominance pattern of each identified haplotype in multiple populations of both species, across their range.

7. Perform comparative analyses on systems with early-run and late-run populations that have been differentially impacted by human activities resulting in differing levels of interbreeding between life-history types, to determine how interbreeding might affect persistence of run type alleles.

Conservation Implications

Subsequent to the technical discussions, the participants discussed how the current state of knowledge should be applied to conservation decisions such as defining units for conservation, listing, and recovery Their individual points are excerpted directly and presented here:

Areas of agreement:

1. After discussion on whether conservation strategies might need to change based on the GREB1L/ROCK1 findings, the participants generally agreed that using patterns of genetic variation throughout the genome remains important for identifying conservation units, rather than identifying units based solely on small genomic regions associated with specific traits.
2. The workshop participants agreed that spring Chinook salmon and summer steelhead occupy a specialized ecological niche—upstream areas accessible primarily during spring flow events—that has made them particularly vulnerable to extirpation or decline due to habitat degradation.
3. The participants generally agreed that the evaluation of risk to early returning population groups (spring Chinook, summer steelhead) needs to consider what we now know about the genetic basis of adult return time.
4. The participants generally agreed that the finding that the early run trait has a simple genetic basis implies that it is at greater risk of loss than if it were highly polygenic because loss of the “early” allele(s) equates to the loss of the phenotype.

Areas of uncertainty:

1. One area of uncertainty and potential disagreement at the workshop was the degree to which run timing diversity in spring Chinook salmon is partitioned among populations versus among individuals within a population.
2. The extent to which observed contemporary levels of interbreeding between individuals with early and late run timing would be typical under historical environmental conditions is unknown
3. Understanding the conservation implications of dominance patterns at the GREB1L/ROCK region is also important and is complicated because of tradeoffs between the probability of persistence of the early-run allele and the feasibility of starting new early-run populations.
4. The dominance-recessive relationships might influence the success of colonization events.

5. Regardless to what extent current levels of interbreeding are a consequence of human mediated habitat alterations, such interbreeding, and the common occurrence of heterozygotes at the GREB1L/ROCK1 region presents challenges for status monitoring, recovery planning, and other management actions.
6. Improved strategies are needed for monitoring run timing and associated genetic variation.
7. What conservation measures can be put into place now with existing knowledge? Conservation measures for spring run that were discussed included potentially shaping fisheries to focus disproportionately on fish with fall run timing, restoring access to spring-run habitat that has been blocked, considering restoring natural barriers that have been modified to increase fall-run access to historically spring-run habitats, and restoring more natural flow regimes (e.g., low summer flows that prevent mature migrating individuals from encroaching on premature habitat). Workshop participants agreed that the presence of heterozygotes does not in itself indicate a threat to the viability of spring-run as these heterozygotes contain alleles that may be important to spring-run restoration. Some workshop participants also noted, however, that in some cases the presence of high proportions of heterozygotes might represent a departure from the historical conditions and a warning sign that the spring-run phenotype is at risk.

Issues Specifically Associated with Steelhead

1. One major factor to consider regarding the conservation implications of the genetics of run timing diversity in steelhead is the existence of conspecific resident rainbow trout populations that may effectively act as reservoirs for the “early” GREB1L/ROCK1 alleles.
2. Another factor to consider for steelhead compared to Chinook is the generally greater amount of life-history diversity found in *O. mykiss*.

Report Citation

[20]Ford, M., K. Nichols, R. Waples, E. C. Anderson, M. Kardos, I. Koch, G. McKinney, M. R. Miller, J. Myers, K. Naish, S. Narum, K. G. O'Malley, D. Pearse, T. Seamons, A. Spidle, P. Swanson, T. Q. Thompson, K. Warheit, and S. Willis. 2020. Reviewing and Synthesizing the State of the Science Regarding Associations between Adult Run Timing and Specific Genotypes in Chinook Salmon and Steelhead: Report of a workshop held in Seattle, Washington, 27–28 February 2020. U.S. Department of Commerce, NOAA Processed Report NMFS-NWFSC-PR-2020-06.

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Appendix E. Peer Review Comments

External Peer Review Solicitation Letters

State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
Fisheries Branch
P.O. Box 944209
Sacramento, CA 94244-2090
www.wildlife.ca.gov

GAVIN NEWSOM, Governor
CHARLTON H. BONHAM, Director

September 14, 2020

«Title» «First_Name» «Last_Name»
«Company_Name»
«Address_Line_1»
«City», «State» «ZIP_Code»
«Email_Address»

RE: UPPPER KLAMATH AND TRINITY RIVERS SPRING CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*) DEPARTMENT OF FISH AND WILDLIFE, STATUS REPORT PEER REVIEW

Dear Reviewer:

Thank you for agreeing to serve as a scientific peer reviewer for the Department of Fish and Wildlife's (Department) Draft Status Review of the Upper Klamath and Trinity Rivers Spring Chinook Salmon (Oncorhynchus tshawytscha). A copy of this report, dated August 25, 2020. is enclosed for your use in that review. The Department seeks your expert analysis regarding the scientific validity of the report and its assessment of the status of the Upper Klamath and Trinity Rivers Spring Chinook Salmon in California.

The Department would appreciate receiving your peer review input on or before October 2, 2020.

The Department seeks your review as part of formal proceedings pending before the California Fish and Game Commission (Commission) under the California Endangered Species Act (CESA). As you may know, the Commission, as a constitutionally established entity distinct from the Department, exercises exclusive statutory authority under CESA to add species to the state lists of endangered and threatened species. (Fish & G. Code, § 2070.) The Department serves in an advisory capacity during listing proceedings, charged by the Fish and Game Code to use the best scientific information available to make related recommendations to the Commission. (Fish & G. Code, § 2074.6.)

The Commission received a Petition to List the list the Upper Klamath-Trinity Rivers (UKTR) Spring Chinook Salmon as endangered under the CESA. On November 8, 2018, the Department transmitted its initial evaluation, entitled *Evaluation of the petition From the Karuk Tribe and the Salmon River Restoration Council to List Upper Klamath Trinity River Spring Chinook Salmon (Oncorhynchus tshawytscha) as Threatened or*

Endangered, to assist the Commission in making a determination as to whether the petitioned action may be warranted based on the sufficiency of scientific information.

(Fish & G. Code, §§ 2073.5 & 2074.2; Cal. Code Regs., tit. 14, § 670.1, subds. (d) & (e).) Focusing on the information available to it relating to each of the relevant categories, the Department recommended to the Commission that the Petition be accepted.

The draft report forwarded to you today reflects the Department's effort to identify and analyze available scientific information regarding the status of of UKTR spring Chinook Salmon in California. An endangered species is defined under the CESA as "a native species or subspecies…which is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease." (Fish and G. Code, § 2062.) A threatened species is defined as "a native species or subspecies…that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by [CESA]." (Fish and G. Code, § 2067.) At this time, the Department recommends that listing the species under CESA is not warrented. The Department's scientific analysis shows that the spring and fall ecotypes are a single ESU with active gene flow between fish having each run timing phenotype. This ESU as a whole is widley distributed in the Klamath Basin andexhibits stable abundance in the tens of thousands of annual spawners. We underscore, however, that scientific peer review plays a critical role in the Department's effort to develop and finalize its recommendations to the Commission as required by the Fish and Game Code.

Because of the importance of your effort, we ask you to focus your review on the scientific information regarding the status of UKTR spring Chinook Salmon in California. As with our own effort to date, your peer review of the science and analysis regarding each of the listing factors prescribed in CESA (Cal. Code Regs., Tit. 14, § 670.1(i)(1)(A)) (i.e., present or threatened habitat modification, overexploitation, predation, competition, disease, and other natural occurrences or human-related activities that could affect the species) are particularly important.

Please note the Department releases this peer review report to you solely as part of the peer review process, and it is not yet public.

For ease of review, I invite you to use "Track Changes" in Microsoft Word, or provide comments in list form by page number, section header, and paragraph using the attached comment form. Please submit your comments electronically to Daniel Kratville, Senior Environmental Scientist (Supervisor) with the Fishereis Branch at [redacted] or at the address in the letterhead above. If you have any questions, you may reach Daniel Kratville by phone at [redacted].

If there is anything the Department can do to facilitate your review, please let me know.

Thank you again for your contribution to the status review effort and the important input it provides during the Commission’s related proceedings.

Sincerely,

Kevin Shaffer, Chief
Fisheries Branch
Department of Fish and Wildlife

Enclosure

ec: **Department of Fish and Wildlife**

Stafford Lehr, Deputy Director
Wildlife and Fisheries Division
[redacted]

Kevin Shaffer, Chief
Fisheries Branch
[redacted]

Jonathan Nelson, Fisheries Branch
Anadromous Program Manager
[redacted]

Daniel Kratville, Fisheries Branch
Senior Environmental Scientist (Supervisor)
[redacted]

Michael Lacy, Fisheries Branch
Senior Environmental Scientist (Specialist)
[redacted]

External Peer Review Comments

Comments from Dr. Andrew Kinziger

From: Andrew P Kinziger <[redacted]**>**
Sent: Monday, November 9, 2020 10:15 PM
To: Kratville, Daniel@Wildlife <[redacted]>; Nelson, Jonathan@Wildlife <[redacted]>
Subject: Re: UKTRSC Status Peer Review

Hi Daniel and Jonathan,

Attached please find some comments on the document in track changes mode of Word. I wish I had more time to spend on this but I am running out of steam. Like everyone else these days, I am finding it difficult to come up between waves.

I agree with CDFW assertions that Klamath River spring-run does not warrant recognition as a separate ESU.

I am sure you've seen it but colleagues and I have recently published on the genetic basis of spring and fall Chinook in Science. I think it would be a good idea to add these citations to the document, especially the components that support spring and fall can be full-siblings. This latter finding is a strong rebuttal to the idea that spring and fall should be recognized as separate ESUs.

Here is a link to the full paper (and attached):
https://science.sciencemag.org/content/370/6516/609

Also, there is an accompanying commentary (and attached):

https://science.sciencemag.org/content/370/6516/526

Best regards,

Andrew

--

Andrew P. Kinziger, Ph.D.
Professor and Chair
Department of Fisheries Biology
Humboldt State University
[redacted]

[redacted]

Fisheries Biology at HSU: Website, Video

Comments from Dr. Shawn Narum

From: Shawn Narum <[redacted]>
Sent: Wednesday, October 14, 2020 2:52 PM
To: Kratville, Daniel@Wildlife <[redacted]>
Subject: RE: Peer Review - California Endangered Species Act Status Review for Upper Klamath and Trinity Rivers Spring Chinook Salmon (Oncorhynchus tshawytscha)

Hi Dan,

I've completed my review of the report and attached a version with tracked changes with my edits/comments. I read the full document but primarily focused my efforts on the following sections: 2.6, and 8-13.

Overall, this is a very thorough document with polished writing. There are a few particular areas that I noted that could be improved/clarified.

Hope this helps and let me know if you questions.

Shawn

Comments from Dr. Matthew Sloat

WILD SALMON CENTER

To: Jonathan Nelson, Environmental Program Manager, Anadromous Fishes Conservation and Management Program, CA Department of Fish and Wildlife

From: Dr. Matthew Sloat, Science Director, Wild Salmon Center

Re: Review of “California Endangered Species Act Status Review for Upper Klamath and Trinity Rivers Spring Chinook Salmon (*Oncorhynchus tshawytscha*)”

Date: October 26, 2020

Thank you for the opportunity to review “California Endangered Species Act Status Review for Upper Klamath and Trinity Rivers Spring Chinook Salmon (*Oncorhynchus tshawytscha*).”

I made extensive comments and some suggested edits in track changes in the report draft provided to me, as requested by the Department. In several cases I found that my comments required more room than could easily fit within the report itself, so I have written them here.

I have focused my review primarily on the key question of whether the available science could support considering UKT spring Chinook as an Evolutionary Significant Unit separate from UKT fall Chinook and how this information was interpreted in the report.

There are two documents that are particularly relevant to this question and that I rely on heavily in my review. The first is the recent report by Ford et al. (2020) that summarizes information from a February 2020 workshop attended by West Coast salmon geneticists. The goal of the workshop was to characterize the current state of the science regarding the nature of the associations between genetic variation and run timing in Chinook salmon and steelhead.

The second is Waples’ 1991 paper “Pacific Salmon, Oncorhynchus spp., and the Definition of "Species" Under the Endangered Species Act,” which lays out remarkably clear and simple criteria for defining “species” for the purposes of the federal Endangered Species Act. While biologists still debate the biological definition of a species (e.g., Hey 2001), the legal definition of a “species” that forms the basis for ESU designation is refreshingly clear.

The Waples (1991) framework provides a reliable road map for reviewing the large amount of information presented in the Department’s status assessment for UKT spring Chinook. I have mostly organized my comments below within this framework.

The ESU concept: What is the legal definition of a species?

The ESA defines a species in the legal sense 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." As applied to Pacific salmon, a population (or group of populations) is considered “distinct'” (and hence a “species”) for purposes of the ESA if it represents an evolutionarily significant unit (ESU) of the biological species (Waples 1991).

A population (or group of populations) must satisfy two criteria to be considered an ESU: **1)** It must be substantially reproductively isolated from other conspecific population units, and **2)** It must represent an important component in the evolutionary legacy of the species (Waples 1991).

Criterion 1: Substantial reproductive isolation

For the first criterion, reproductive isolation does not have to be absolute, but it must be strong enough to permit evolutionarily important differences to accrue (Waples 1991). As Waples (1991) points out, “With Pacific salmon, reproductive isolation is seldom a black-and-white situation, but rather a question of degree . . .” (p. 13). Consequently, the standards for defining an ESU accommodate for some level of reproductive exchange with other ESUs; they do not require complete reproductive isolation (ESU Policy; 56 FR 68612; November 20, 1991).

Below, I highlight relevant research that informs this criterion in the context of the standards of the ESA and the Department’s status assessment of UKT spring Chinook.

UKT spring Chinook run timing facilitates reproductive isolation from fall Chinook. The relationship between spring Chinook and fall Chinook is consistent with the quote above from Waples (1991). There is some level of reproductive exchange in many if not most of the watersheds where both spring and fall Chinook co-occur (Ford et al. 2020). But there is also a degree of reproductive isolation that is facilitated by spring Chinook entering freshwater considerably earlier than fall Chinook (e.g., Quinn et al. 2016; Davis et al. 2017; Quinn 2018; Thompson et al. 2019; Ford et al. 2020). It is widely known that by entering freshwater early, spring Chinook gain access to upstream areas that are difficult to access or are completely inaccessible for fall Chinook and spring Chinook also spawn significantly earlier (e.g., Quinn et al. 2016; Quinn 2018; Ford et al. 2020).

UKT spring Chinook run timing is under strong genetic control. Importantly, the degree of reproductive isolation exhibited by spring and fall Chinook is sufficient to have allowed evolutionarily important differences to accrue. This is clear from recent work that identified adaptive genetic differences between spring and fall Chinook in a genomic region associated with run timing (Prince et al. 2017; Thompson et al. 2019). There is broad scientific agreement that the expression of a spring run life history depends on having alleles that are distinct from those associated with fall Chinook life history (reviewed in Ford et al. 2020).

Data are consistent with a monophyletic evolution of UKT spring Chinook run timing. Recent research has clarified key aspects of the evolutionary history of spring Chinook, and this research has led to broad scientific agreement on key hypotheses for how the spring Chinook life history evolved (reviewed in Ford et al. 2020). Importantly, the spring Chinook migration does not have a polyphyletic evolution, as has been inferred in the past. In reviewing current scientific agreements and uncertainties on the subject, Ford et al. (2020) make the following statement on the evolution of "early migration" (e.g., spring Chinook) and "late migration" (e.g., fall Chinook) life histories:

"It is also clear, based on available data, that the allelic variants for early migration have not arisen independently via new mutations from the genomic background of late migration individuals in each watershed" (p. 37).

In other words, spring Chinook run timing did not evolve multiple times independently from fall Chinook populations (i.e., spring Chinook run timing does not have a polyphyletic origin).

The available data are, however, consistent with a monophyletic origin of spring Chinook run timing. A single haplotype is associated with the spring Chinook life history in diverse coastal populations in California, Oregon, and Washington, supporting the conclusion that spring run alleles arose from a single evolutionary event that spread through straying among watersheds and positive selection (Prince et al. 2017; Thompson et al. 2019).

The current scientific agreement on the evolution of spring Chinook migration is reconcilable with previous assessments that reached different conclusions. The information above describes broadly accepted scientific agreements on the evolution of spring Chinook life history in coastal populations, including UKT spring Chinook. To summarize again briefly, spring Chinook run timing is under strong genetic control and facilitates a degree of reproductive isolation from fall Chinook. Notably, the alleles associated with spring Chinook run timing have a monophyletic evolutionary history.

These facts provide strong scientific support that spring Chinook are sufficiently reproductively isolated from conspecifics for evolutionary important differences to have accrued, and would seem to clearly meet the first ESU criterion of "substantial reproductive isolation".

The Department's review reaches two conclusions regarding the question of substantial reproductive isolation that are in opposition to the information above. The review erroneously concludes that: 1) UKT spring Chinook evolved multiple times locally from and interbreeding with UTK fall Chinook (i.e., spring Chinook migrations have a polyphyletic origin); and that 2) spring Chinook are not genetically distinct.

To reach these conclusions, the Department draws heavily on a series of studies by Kinzinger and colleagues (Kinzinger et al. 2008a,b; Kinzinger et al. 2013) and earlier studies. In doing so, the Department repeats inferences about the evolution of UKT spring Chinook that were reasonable given the information and technology available at the time those older studies were conducted, but that are now simply known to be incorrect based on more recent research (e.g., Prince et al. 2017; Thompson et al. 2019; reviewed by Ford et al. 2020).

With regard to the first conclusion, as I summarized above there is now broad scientific agreement that UKT spring Chinook run timing does not have a polyphyletic evolutionary history (see Ford et al. 2020). Previous studies that inferred a polyphyletic evolutionary history for spring run timing relied on patterns of variation at neutral genetic markers to reach that conclusion. Neutral genetic markers, by definition, are loci that are not under selection. Therefore, in order to use neutral markers to make inferences about the evolutionary history of spring Chinook, those studies had to assume that patterns of variation at neutral markers were highly correlated with patterns of adaptive genetic variation associated with run timing.

Based on this assumption, these studies inferred a polyphyletic evolutionary history from the pattern that spring and fall Chinook populations from the same watershed were more similar at neutral markers than were spring Chinook populations from different watersheds. This gave rise to the view that spring Chinook run timing evolved multiple times independently. Importantly, however, these studies did not actually measure variation at loci associated with Chinook run timing because these loci had not been discovered yet.

Because it has long been known that genetic similarity at neutral markers can mask genetic differences at loci under strong selection (Slatkin 1987), there was always reason to treat the polphyletic origin of spring Chinook run timing as a hypothesis with some support, but certainly not proven. Now that researchers have developed the ability to measure patterns of genetic variation at the loci associated with Chinook run timing, it is clear that this hypothesis is false. The alleles for the early migration timing of UKT spring Chinook arose once from a single evolutionary event and cannot reasonably be expected to re-evolve (Prince et al. 2017; Thompson et al. 2019; reviewed in Ford et al. 2020).

Similarly, the Department's second conclusion that spring and fall Chinook are not genetically distinct is demonstrably not true. As established by recent research on the genetic basis for spring Chinook run timing, there are clear genetic differences in the genomic region responsible for spring Chinook migrations and fall Chinook migrations. These genetic differences occur in a region of the genome that has been associated with a variety of physiological and behavioral traits such as metabolism, hormone regulation, and fasting (see references cited in Prince et al. 2017), that should influence the fitness of a spring Chinook life history that requires month's-long fasting while enduring the final stages of maturation.

The fact that there are some genetic similarities between spring and fall Chinook does not preclude there being adaptive genetic differences between spring and fall Chinook that are evolutionarily significant.

Human impacts influence reproductive connectivity between spring and fall Chinook. The primary hypothesized advantage of the spring Chinook life history is that earlier migration timing allows for access to exclusive or nearly-exclusive spatiotemporal spawning habitat (i.e., they access habitat that is difficult for fall Chinook to access due to physical factors such as temperature, flow, and seasonal migration barriers) (Quinn et al. 2016; Quinn 2018; Ford et al. 2020). However, there is also general scientific agreement that human impacts have modified reproductive connectivity between spring and fall Chinook (Ford et al. 2020). This point is relevant to the Department's comparisons of Chinook genetic population structure between the Central Valley (CV), in which spring Chinook are considered an ESU independent of fall Chinook and the UKT in which they are not.

The contrast in contemporary genetic structure of Chinook in the Klamath and the Central Valley is potentially interesting. Unfortunately, historical population genetic structure in both systems is largely unknown. Current genetic structure in both systems undoubtedly reflects long histories of anthropogenic change.

It seems very plausible that patterns of genetic similarity within Chinook run timing groups in the CV is largely an artifact of the extirpation of spring Chinook from all but a localized cluster of geographically proximate remnant populations in Mill, Deer, and Butte creeks, and the homogenization of fall Chinook stocks throughout the CV from hatchery introgression (Williams and May 2005). Consequently, there is a high degree of uncertainty that overall genetic structure in the CV provides a reliable reference model from which to identify or evaluate conservation units in the UKT.

In the UKT, human influences have also left their signature on Chinook genetic structure. Dams on the mainstem Klamath, Shasta, and Trinity prevented access to historical spring Chinook habitat, resulting in local extirpation of populations above mainstem dams on the Klamath and contributing to the extirpation of spring Chinook in the Shasta. The mainstem Trinity River and the Salmon River appear to be the main remaining areas of spring Chinook production in the UKT basin.

In the Trinity, the population is dominated by hatchery fish and the dam has increased reproductive exchange between spring and fall Chinook, including the mixing of spring and fall Chinook within the hatchery program. This situation appears analogous to that described by the Department for the Feather and Yuba rivers of the Central Valley, where heavy introgression between spring and fall runs appears to be a result of previous hatchery practices at Feather River Hatchery, along with dam construction and water management.

In the Salmon River, there is also reason to believe that human impacts have increased reproductive exchange between spring and fall Chinook. Notably, habitat alteration in the Salmon River (e.g., documented modification of Bloomer Falls and other low flow barriers that historically hindered fall Chinook migrations) has likely increased reproductive connectivity between spring and fall Chinook (Olson and Dix 1991).

Consequently, it seems highly plausible that human-driven habitat modification has increased reproductive connectivity between spring and fall Chinook in the mainstem Trinity River and in the Salmon River, as has been seen in many other systems.

Indeed, Ford et al. (2020) summarize a widespread phenomenon of increased reproductive connectivity between spring and fall Chinook in their review: ". . . in many locations, there are strong indications that human-driven habitat modifications have increased opportunities for interbreeding. Substantial numbers of heterozygotes have been observed in contemporary samples from the Salmon (Klamath, CA), Rogue (OR), and Chehalis (WA) River basins, indicating high levels of current and/or recent interbreeding among fall and spring-run fish. For example, in the Salmon River, the mature, heterozygous, and premature genotypes were found in nearly Hardy-Weinberg equilibrium proportions in one data set, suggesting spring and fall Chinook salmon are currently interbreeding at a high rate. However, documented habitat alteration in the Salmon River (e.g., modification of Bloomer Falls and other low flow barriers that previously hindered fall-run migration) has likely increased the opportunity for interbreeding compared to historical times (Olson and Dix 1991). In the Rogue River, data from an upper-basin fish counting station collected from 1942 to 2009 suggest a major increase in the frequency of fall-run fish accessing historical spring-run habitat after a dam was constructed and a concomitant increase in intermediate migrators (i.e., putative heterozygotes) (ODFW 2000; Thompson et al. 2019). Importantly, in these Rogue River data, the frequency of fall run and intermediate migrators in the Upper Rogue was consistently low across almost 40 years of data before a substantial increase corresponding to the construction of Lost Creek Dam in 1977. In the Chehalis basin, U.S. Fish and Wildlife surveys also noted a loss in the spatiotemporal segregation between spring and fall-run spawning after a dam was built (Hiss et al. 1985), and a substantial proportion of heterozygotes observed in the Chehalis (Thompson presentation) were sampled near this dam. Therefore, it seems reasonable to conclude that, although the degree of demographic interaction between spring and fall fish naturally varies over time and that some degree of interbreeding is normal and expected, human activities have notably increased interbreeding in many locations" (p. 36).

Consequently, high levels of reproductive exchange between spring and fall Chinook in the UKT observed in contemporary studies likely reflect the influence of human-driven habitat modifications and hatcheries on population genetic structure.

Thus, human-driven habitat modifications and hatchery practices can influence patterns of Chinook population genetic structure in different watersheds in starkly contrasting ways. In the CV, the specific combination of habitat and hatchery impacts are likely to have decreased overall genetic similarities between extant spring and fall Chinook populations. In the Klamath, these impacts are likely to have increased overall genetic similarities between extant spring and fall Chinook populations. In either case, contemporary patterns of overall genetic similarity between spring and fall Chinook populations in the UKT and CV are likely to be more informative about the timing, locations, and types of human impacts specific to each basin than they are about the evolutionary history of spring Chinook run timing.

Criterion 2: Importance of evolutionary legacy

The second criterion is the evolutionary legacy of a species, which Waples (1991) describes as "the genetic variability that is a product of past evolutionary events and which represents the reservoir upon which future evolutionary potential depends" (p. 13).

To assess criterion 2, the potential importance in the evolutionary legacy of the species, Waples (1991) posed the three following questions:

1) Is the population genetically distinct from other conspecific populations?

2) Does the population occupy unusual or distinctive habitat?

3) Does the population show evidence of unusual or distinctive adaptation to its environment?

Here, I outline key spring Chinook research that informs these questions.

1) Is the population genetically distinct from other conspecific populations?

Much of the discussion above related to the question of reproductive isolation (Criterion 1) also addressed the question of genetic distinctness of spring Chinook. There is strong scientific evidence to support an answer of yes to this question. Recent genomics research has demonstrated the strong genetic basis for run timing in coastal spring Chinook salmon that resulted from a single evolutionary event that spread through straying and positive selection (Prince et al 2017). Subsequent work has clarified the genomic region associated with this evolutionary event (Thompson et al. 2019; Ford et al. 2020). Research has also demonstrated that alleles associated with spring Chinook phenotypes do not persist in fall Chinook populations from the same watershed in places where spring Chinook runs are extirpated (Thompson et al. 2019). There is now broad scientific agreement that spring Chinook are genetically distinct from fall Chinook in the region controlling run timing (among other potentially associated traits) (Ford et al. 2020).

2) Does the population occupy unusual or distinctive habitat?

There is strong scientific evidence that the answer to this question is yes. As mentioned above in relation to the question of reproductive isolation (criterion 1), relative to conspecifics, spring Chinook occupy distinct habitat. Spring Chinook migrate farther upstream than fall Chinook into areas of watersheds that are often above seasonally impassable barriers that prevent or significantly delay fall Chinook passage, or spring Chinook use areas that otherwise have a low likelihood of use by fall Chinook (Connor et al. 2003; Quinn et al. 2016; Thompson et al. 2019; Ford et al. 2020). These habitats often have distinct temperature and flow regimes relative to those used by fall Chinook (e.g., Connor et al. 2003; Beechie et al. 2006). Indeed, the recent workshop led by Ford et al. (2020) reached broad scientific agreement that spring Chinook salmon occupy a “specialized ecological niche” (p. 38).

3) Does the population show evidence of unusual or distinctive adaptation to its environment?

There is strong scientific evidence that the answer to this question is yes. The unique run timing of spring Chinook and other associated traits (e.g., extended fasting, high fat stores) are genetic adaptations that enable access to and increase fitness in distinctive habitats described above (Quinn et al. 2016).

In light of the above, my interpretation is that there is strong scientific evidence that UKT spring Chinook meet the criteria to be considered a “species” under the legal standards of the ESA.

This conclusion is different from that of the Department, but I hope my review will be useful to the Department as they move forward with any refinements to this assessment.

Sincerely,

Matthew R Sloat

Dr. Matthew Sloat

Wild Salmon Center

References (I did not include some references that are cited within the Department's review)

Beechie, T. J., Buhle, E. R., Ruckelshaus, M. H., Fullerton, A. H., & Holsinger, L. (2006). Hydrologic regime and the conservation of salmon. Biological Conservation, (130), 560–572.

Connor, W.P., Piston, C.E. and Garcia, A.P., 2003. Temperature during incubation as one factor affecting the distribution of Snake River fall Chinook salmon spawning areas. Transactions of the American Fisheries Society, 132(6), pp.1236-1243.

Davis, C.D., Garza, J.C. and Banks, M.A., 2017. Identification of multiple genetically distinct populations of Chinook salmon (Oncorhynchus tshawytscha) in a small coastal watershed. Environmental Biology of Fishes, 100(8), pp.923-933.

Ford, M, Krista Nichols, Robin Waples, Eric C. Anderson, Marty Kardos, Ilana Koch, Garrett McKinney, Michael R. Miller, Jim Myers, Kerry Naish, Shawn Narum, Kathleen G. O'Malley, Devon Pearse, Todd Seamons, Adrian Spidle, Penny Swanson, Tasha Q. Thompson, Ken Warheit, Stuart Willis. 2020. Reviewing and synthesizing the state of the science regarding associations between adult run timing and specific genotypes in Chinook salmon and steelhead. Report of a workshop held in Seattle, WA 27-28 February 2020.

Hey, J., 2001. The mind of the species problem. Trends in Ecology & Evolution, 16(7), pp.326-329.

Olson AD, Dix OJ. (1991) Lower Salmon River Sub-basin Fish Habitat Condition and Utilization Assessment 1990/1991 Final Report. USDA – Forest Service, Klamath National Forest.

Prince, D. J., O'Rourke, S. M., Thompson, T. Q., Ali, O. A., Lyman, H. S., Saglam, I. K., … Miller, M. R. (2017). The evolutionary basis of premature migration in Pacific salmon highlights the utility of genomics for informing conservation. Science Advances, 3(8), e1603198.

Quinn, T. P., McGinnity, P., & Reed, T. E. (2015). The paradox of 'premature migration' by adult anadromous salmonid fishes: Patterns and hypotheses. Canadian Journal of Fisheries and

Aquatic Sciences. https://doi.org/10.1139/cjfas-2015-0345

Slatkin. (1987) Gene flow and the geographic structure of natural populations. Science 236: 787-792.

Thompson, T. Q., Bellinger, M. R., O’Rourke, S. M., Prince, D. J., Stevenson, A. E., Rodrigues, A. T., … Butler, V. L. (2019a). Anthropogenic habitat alteration leads to rapid loss of adaptive variation and restoration potential in wild salmon populations. Proceedings of the National Academy of Sciences, 116(1), 177–186.

Waples, R.S., 1991. Pacific salmon, Oncorhynchus spp., and the definition of" species" under the Endangered Species Act. Marine Fisheries Review, 53(3), pp.11-22

Comments from Dr. Christian Smith

From: Smith, Christian <[redacted]>
Sent: Tuesday, September 29, 2020 4:26 PM
To: Kratville, Daniel@Wildlife <[redacted]>
Subject: Re: [EXTERNAL] Peer Review - California Endangered Species Act Status Review for Upper Klamath and Trinity Rivers Spring Chinook Salmon (Oncorhynchus tshawytscha)

Dr. Kratville,

Thank you for providing me with an opportunity to review this document. Per the directions in the Memo, I used "Track Changes" in Microsoft Word to add comments and suggest edits (see attached draft).

In general, I believe that the sources cited in the Status Review represent the best available scientific information for evaluating the status of UKTR spring Chinook Salmon. I agree with the conclusion of the authors of the Status Review that the abundant evidence of active gene flow between fish having each run timing phenotype argues strongly in favor of UKTR spring Chinook Salmon being one component of a larger UKTR Chinook salmon population (which includes spring and fall). I also agree with their assessments of the risks that habitat modification, overexploitation, predation, competition, disease, and other factors pose to the combined (spring + fall) population of UKTR Chinook Salmon.

It is obvious that a tremendous effort went in to gathering the information presented and to writing this document. I believe the authors did an excellent job, and I hope that they find my comments useful. If you have questions or would like more information on any of the issues I noted, please let me know.

Best regards,

Christian Smith

Regional Geneticist

US Fish & Wildlife Service

[redacted]

External Peer Review Track Changes and Submitted Comments

The following section contains all peer review comments received by the Department. Comments are coded by the initials of reviewers as follows:

- LM is Mr. Michael Lacy
- SN is Dr. Shawn Narum (Peer Reviewer)
- SC is Dr. Christian Smith (Peer Reviewer)
- MOU is Dr. Andrew Kinziger (Peer Reviewer)
- MS is Dr. Matthew Sloat (Peer Reviewer)
- AC is for notes to assist with Web Content Accessibility Guidelines requirements

STATE OF CALIFORNIA
NATURAL RESOURCES AGENCY
DEPARTMENT OF FISH AND WILDLIFE

REPORT TO THE FISH AND GAME COMMISSION

California Endangered Species Act Status Review for Upper Klamath and Trinity Rivers Spring Chinook Salmon (Oncorhynchus tshawytscha)

Commented [LM1]: Andrew Kinziger peer review comments. Nov 2020.

Commented [LM2]: Peer review comments from Matt Sloat, Oct 2020

Commented [LM3]: Peer Review comments. Shawn Narum. October 2020.

Commented [LM4]: Peer review comments from Christian Smith, USFWS, Abernathy Lab, October 2020.

Commented [AC5]: Table formatting changes throughout document provided by Andrew Kinziger.

CHARLTON H. BONHAM, DIRECTOR
CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE
Peer Review Draft

Commented [MOU6]: Are you sure that is a photograph of Chinook salmon? It might be, I just know for sure because I can see spots on the caudal fin and shape of the anal fin….

August 25, 2020

Suggested citation:

California Department of Fish and Wildlife (CDFW). 2020. California Endangered Species Act Status Review for Upper Klamath and Trinity Rivers Spring Chinook Salmon *(Oncorhynchus tshawytscha).* A Report to the California Fish and Game Commission. California Department of Fish and Wildlife, 1416 Ninth Street, Sacramento CA 95814. 215 pp., with appendices

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Acknowledgements

Michael K. Lacy (California Department of Fish and Wildlife [CDFW] Fisheries Branch) prepared this report. Erica Meyers (CDFW Fisheries Branch) contributed invaluable writing, research, and edits to numerous sections throughout the document. Brett Kormos, Jennifer Simon, and Kandice Morgenstern (CDFW Ocean Salmon Project) conducted analyses and wrote essential sections on ocean conditions and ocean harvest. Jeff Rodzen (CDFW Fisheries Genetics) contributed to sections on genetics and genomics. Laura Patterson (CDFW Wildlife Branch) provided important insights to listing criteria and review. Thanks go out to the following additional Department staff and scientists who contributed research, writing, and/or data: Wade Sinnen, Darrick Muir, Patrick Brock, Michael van Hattem, Steve Baumgartner, Kenneth Lindke, Dan Troxel, Andrew Hill, and Joseph Maret. Maija Meneks and LeRoy Cyr (USFS) provided important details on UKTR spring and fall Chinook Salmon spawning distribution in the Salmon River. The final document was improved by comments from internal DFW and peer reviewers. John Kelly (CDFW Fisheries Branch) provided copy edits and suggestions that substantially improved a previous draft of this status review. The conclusions in this report are those of the Department and do not necessarily reflect those of the reviewers.

Thanks to Nathan McCanne, AmeriCorps Watershed Steward, Six Rivers National Forest, for the cover photo of a Salmon River Upper Klamath Trinity Rivers spring Chinook Salmon.

Commented [MOU7]: OK – sounds like you do have a validated photograph…

Glossary and Acronyms

Allozymes: Allelic variants of enzymes (proteins) encoded by structural genes used as markers in (especially older) population genetics studies.

Adaptive trait: A genetic trait directly associated with the ability of an organism to maximize its survival and/or reproductive success.

Commented [MOU8]: Not just genetic but more importantly “heritable (in the narrow sense)”

Adipose fin-clip: Adipose fin removed on some or all hatchery-origin fish to indicate that they were produced in a hatchery. Fish with an adipose fin-clip may or may not also contain a coded wire tag.

Alleles~~Allele~~: ~~One of two or more a~~Alternative~~alternative~~ forms of a gene that arise by mutation and are found at the same place on a chromosome. Salmon are diploid organisms that possess two alleles for each gene, derived ~~one~~ from each parent.

Commented [AC9]: Changes made by reviewers (in this order): Andrew Kinziger, Microsoft Office User, Andrew Kinziger

Commented [AC10]: Changes by Andrew Kinziger

Alevin: An early life stage in salmonids that occurs immediately after hatching, also called “yolk-sac larvae~~.~~”.~~.”~~ Alevin retain a yolk-sac that they use for nourishment and remain hidden in the gravel until they grow into fry.

Assortative mating: A mating pattern and form of sexual selection in which individuals with similar phenotypes mate with one another more frequently than expected by chance.

CDFW: California Department of Fish and Wildlife. Also “the Department.” Previously named California Department of Fish and Game.

Commission: The California Fish and Game Commission.

CESA: California Endangered Species Act

Climate change: A change in global or regional climate patterns. In particular, a change apparent from the mid to late 20th century onwards attributed largely to increased levels of atmospheric carbon dioxide produced by use of fossil fuels.

Cohort replacement rate: A parameter that compares the number of spawning fish in the current year to the number of spawning fish one generation previous. Used to estimate whether a population is increasing, decreasing, or not changing in size over generational time.

CWT: Coded wire-tag. A (usually) numbered, very small wire tag inserted into the rostrum of some hatchery-origin fish. Fish with a coded wire-tag are usually identifiable by an external mark, typically ~~having~~ an adipose fin-clip.

Commented [AC11]: Changes made by Microsoft Office User

DNA: Deoxyribonucleic acid; Carrier of genetic information from one generation to the next in most organisms.

DPS: Distinct Population Segment. Under the federal ESA, the smallest division of a taxonomic species permitted to be protected under the U.S. Endangered Species Act. For Pacific salmon the DPS is synonymous with Evolutionarily Significant Unit.

Ecotype: A variant group that displays a distinct set of characters, but for which the phenotypic differences are too few or too subtle to warrant it being classified as a subspecies. Although ecotypes exhibit phenotypic differences (e.g., in morphology or physiology) stemming from environmental heterogeneity, they are capable of interbreeding with other geographically adjacent ecotypes.

Commented [MOU12]: It is important to give some careful thought to this definition as there is some that would suggest that “life histories” is a better term to describe spring and fall Chinook salmon. I’ve always thought of an ecotype of a genetically distinct population that exhibits local adaptation.

Effective population size: Abbreviated N_e. The number of individuals ~~that~~ in an idealized population would need to have for genetic drift (or inbreeding) to be the same in the idealized population as in the real population. In some cases, the number of successful breeding individuals in a population.

Commented [MOU13]: Ne is the number of individuals in an idealized population that experience drift as the population under consideration, where an idealized population has equal sex ratio, constant population size, and no variance in reproductive success.

Commented [MOU14]: Strictly speaking, this is not correct.

Endangered species: Under the California Endangered Species Act, a native species or subspecies of a bird, mammal, fish, amphibian, reptile, or plant which is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease” (California Fish and Game Code §2062).

ENSO: El Niño Southern Oscillation. The interaction between the atmosphere and ocean in the tropical Pacific that results in periodic variation between below-normal and above-normal sea surface temperatures and dry and wet conditions over time.

Formatted: Spanish (United States)

ESA: ~~Federal~~ United States Endangered Species Act.

Commented [AC15]: Changes made by Microsoft Office User

ESU: Evolutionarily Significant Unit. The distinct unit of a biological species that defines a salmon “species” under the ~~federal~~ ESA of the United States.~~.~~ An ESU is a group of organisms (a population or group of populations) that (1) is substantially reproductively isolated from other conspecific population~~ units~~s, and (2) represents an important component in the evolutionary legacy of the species. In Pacific salmon, ESUs are the level at which endangered species management actions are directed.

Commented [AC16]: Changes made by Microsoft Office User

Extinction: The cessation of existence, or the process leading to the cessation of existence, of a species or other taxon. The moment of extinction is generally considered to be the death of the last individual of that species or taxon, although the capacity to breed and recover may have been lost before this point.

Extirpation: Also called “local extinction.” The cessation of existence of a species or other taxon in a defined geographic area, though the species or taxon still exists elsewhere.

FMP: Fishery Management Plan. A monitoring and management plan required under the federal ESA for fisheries that affect listed stocks.

Fpp: Fish per pound. Used by hatcheries to estimate fish size. A sample of fish are counted, and the number divided by their weight in pounds.

Fry: The life stage of salmonids that occurs when alevin absorb the yolk-sac, emerge from the gravel, and begin to feed on external food items.

Gene: Traditionally defined as a sequence of nucleotides in DNA or RNA (ribonucleic acid) that encodes the synthesis of a gene product, either RNA or protein. Genes are more generally defined as locatable regions of genomic sequence, corresponding to a unit of inheritance, which is associated with regulatory regions, transcribed regions, and/or other functional sequence regions.

Gene association: When one or more genotypes within a population co-occur with a phenotypic trait more often than would be expected by chance occurrence.

Genetic diversity: The total number and type of characteristics in the genetic makeup of a species or other taxonomic or non-taxonomic group. Genetic diversity is distinguished from genetic variation, the tendency of genetic characteristics to differ.

Genetic drift: Random changes in allele frequencies from generation to generation in finite populations. Genetic drift ~~over time that is~~ are an especially important determinant of genetic diversity ~~reduction~~ in small populations.

Commented [SC17]: Plural / singular

Commented [AC18]: Changes also made by Microsoft Office User

Genomics: An interdisciplinary field of biology and biotechnology that applies genetic and molecular biology techniques to the study of structure, function, evolution, mapping, and editing of genomes. A genome is an organism's complete set of DNA, including all its genes.

Commented [MOU19]: I would emphasize at the start that genomics implies that you are somehow surveying the full genome of an individual, even if it is a reduced representation method.

Geometric mean: A special type of average calculated by multiplying values and then taking the n^{th} root of the product. Characterizes central tendency in a way that minimizes the effect of outliers in widely varying data sets. (See text for calculations.)

Grilse: A salmon that has returned to spawn after only one winter at sea.

***GREB1L*:** A gene region on chromosome 28 in Chinook Salmon and Steelhead associated with early adult migration behavior.

Haplotype: A set of DNA variations (polymorphisms) that tend to be inherited together. A haplotype can refer to a combination of alleles or to a set of single nucleotide polymorphisms (SNPs) found on the same chromosome.

Hatchery-origin: Abbreviated HO. Fish that were produced and raised in a hatchery for some portion of their life cycle. (See Natural-origin.)

Heterozygous: Refers to the condition of having inherited different forms (alleles) of a gene from each parent. (See Homozygous.)

Homozygous: Refers to the condition of having inherited identical forms (alleles) of a gene from each parent. (See Heterozygous.)

Inbreeding depression: A reduction in fitness occurring because of mating among ~~excessively~~ closely related individuals.

Commented [AC20]: Changes made by Microsoft Office User

Introgression: Gene flow from one species or defined genetic group into the gene pool of another by the repeated backcrossing of hybrids with one or both of its parent “species.”

IUCN: International Union for the Conservation of Nature. Founded in 1948, the world’s oldest and largest global environmental organization.

Jack: A salmonid life-history strategy in which a proportion of males mature and return to freshwater after only one summer at sea. Also, individuals that exhibit this strategy.

Commented [MOU21]: These are typically 2 year-old Chinook salmon.

Commented [MOU22]: Not sure what this means…

Kype: In many salmonids, such as Chinook Salmon, the hooked extension to the lower jaw that develops in males prior to reproduction. This secondary sexual characteristic is believed to help establish dominance hierarchies and access to spawning opportunities.

Commented [MOU23]: I think it is the upper in sockeye…

Microsatellite DNA: Repetitive segments of noncoding DNA scattered throughout the genome between and/or within genes. Often used as genetic markers because of their naturally occurring high variability in repeat number between individuals due to their high mutation rate.

Commented [MOU24]: May want to include that these are short tandemly repeated DNA segments, such as dinucleotide, trinucleotide, or tetranucleotides.

Monophyletic group: Also called a clade. A group of organisms that consists of all the descendants of a common ancestor, or more precisely, of an ancestral population. (See Polyphyletic.)

Natural-origin: Abbreviated NO. Fish that were produced and raised in the wild without human assistance. (See Hatchery-origin.)

Commented [MOU25]: A fish may be considered NO even if it one generation removed with parents that we spawned in a hatchery. Might good to include this because I think there some confusion on this…

NMFS: National Marine Fisheries Service, also known as NOAA Fisheries. The primary federal fisheries agency for anadromous salmonids.

Parr: The freshwater life stage of salmonids, prior to seaward migration. Parr are usually juveniles, although a small percentage of parr in some species develop mature testes.

Commented [MOU26]: Parr is from the markings or morphology too, right…

PDO: Pacific Decadal Oscillation. A recurring pattern of ocean-atmosphere climate variability centered over the mid-latitude Pacific basin. The PDO is characterized as warm or cool surface waters in the Pacific Ocean north of 20°N latitude.

PFMC: Pacific Fishery Management Council. The body that regulates commercial and recreational fishing in non-state ocean waters of the Pacific Ocean.

pHOS; Proportion of hatchery-origin spawning fish. The annual proportion of hatchery-origin fish that spawn in the wild.

PNI: Proportionate natural influence. A measure of the influence of hatcheries as a selective factor driving evolution in a combined hatchery and natural spawning system. $PNI \geq 0.5$ is desirable for most integrated systems, except for conservation programs that target $PNI \geq 0.67$. (See text for calculations.)

Commented [MOU27]: What is the difference between "proportion" and "proportionate"…?

pNOB: Proportion of natural-origin broodstock. The annual proportion of natural-origin fish used as Broodstock in a hatchery program.

Polyphyletic group: A group of organisms that have been grouped together but do not share an immediate common ancestor. (See Monophyletic.)

Population: Organisms of the same species that live in the same place at the same time, with the capability of successfully interbreeding. Populations are sufficiently reproductively isolated to have their own distinct population dynamic trajectories.

Population component: Term used in this document to mean the members of a given ecotype that live in the same geographic area.

Population genetics: A field of biology that studies the genetic composition of biological populations, and the changes in genetic composition that result from the operation of various factors including genetic drift and natural selection.

Rkm: River kilometer. A measure of distance in kilometers along a river from its mouth. River kilometer numbers begin at zero and increase further upstream.

Commented [MOU28]: Delete? Not just from the mouth…

RM: River mile. A measure of distance in miles along a river from its mouth. River mile numbers begin at zero and increase further upstream.

Commented [MOU29]: Same as above?

SNP: Single nucleotide polymorphism. DNA sequence variations that occur when a single nucleotide (adenine, thymine, cytosine, or guanine) in a sequence is altered.

Salmonid: Members of the ray-finned fish family Salmonidae which contains salmon, trout, chars, freshwater whitefishes, and graylings.

Semelparity: A reproductive strategy in which organisms reproduce one time before dying (contrast to *Iteroparity*, in which organisms reproduce multiple times during their lifetime).

Smolt: The seaward migratory phase of salmon. While still in fresh water, fish undergoing smoltification experience a host of physiological, morphological, and behavioral changes that prepare them for migration to and entrance into salt water.

Species of Special Concern: Any California species, subspecies, or other taxon that has been placed on the California list of Species of Special Concern.

Straying: Return of salmonid spawning fish to a location other than the stream in which their parents spawned. Also used to refer specifically to hatchery-origin fish that return to natural spawning areas instead of their hatchery/ stream of origin.

Threatened species: A threatened species under CESA is a native species or subspecies that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by the CESA (Fish and Game Code, § 2067). (See Endangered Species.)

USBR: US Bureau of Reclamation

USFS: US Forest Service

USFWS: US Fish and Wildlife Service.

Viable population size: Number of individuals required for a population to persist for a specified time (usually 100 years) into the future.

Volitional release: A hatchery-origin juvenile release strategy that allows juveniles to move directly from hatchery to river as they become physiologically ready to migrate. Contrast with non-volitional release in which hatchery-origin juveniles are released on a given date regardless of physiological readiness.

Commented [MOU30]: Sorry about all of the nitpicky comments on the definitions. I hope that you find them useful…

A note on scientific and common names

Scientific and common names for fish used throughout this report conform to the standards of the American Fisheries Society. Common names for species are capitalized but families, group names, life history variants, ESUs, DPSs, and ecotypes are lower case (e.g., Pacific salmon, Chinook Salmon vs. fall Chinook Salmon; Rainbow Trout vs. steelhead). The same format is used for bird names, per the standards of the avian professional societies. Common names for other taxa are not capitalized, with the exception of proper nouns.

Executive Summary

[To be completed after review]

1. Introduction

1.1 Candidacy Evaluation

The California Endangered Species Act (CESA) sets forth a two-step process for listing a species as threatened or endangered. First, based on a petition for listing received from the public or another agency, the Commission determines whether to designate a species as a candidate for listing by determining whether the petition provides “sufficient information to indicate that the petitioned action may be warranted.” (Fish & Game Code, § 2074.2(e)(2).) If the petition is accepted for consideration, the second step requires the California Department of Fish and Wildlife (the Department) to produce, within 12 months of the Commission’s acceptance of the petition, a peer reviewed report based upon the best scientific information available that indicates whether the petitioned action is warranted. (Fish & Game Code, § 2074.6.) The Commission, based on that report and other information in the administrative record, then determines whether the petitioned action to list the species as threatened or endangered is warranted. (Fish & Game Code, § 2075.5.)

A petition to list a species under CESA must include “information regarding the population trend, range, distribution, abundance, and life history of a species, the factors affecting the ability of the population to survive and reproduce, the degree and immediacy of the threat, the impact of existing management efforts, suggestions for future management, and the availability and sources of information pertinent to the status of the species. The petition shall also include information regarding the kind of habitat necessary for species survival, a detailed distribution map, and other factors the petitioner deems relevant.” (Fish & Game Code, § 2072.3; *see also* Cal. Code Regs., tit. 14, § 670.1, subd. (d)(1).) The species’ range for the Department’s petition evaluation and recommendation refers to the geographic range boundaries of the species in California. (*Cal. Forestry Assn. v. Cal. Fish and Game Com.* (2007) 156 Cal. App. 4th 1535, 1551.)

Within ten days of the receipt of a petition, the Commission must refer the petition to the Department for evaluation. (Fish & Game Code, § 2073.) The Commission must also publish notice of receipt of the petition in the California Regulatory Notice Register. (Fish & Game Code, § 2073.3.) Within 90 days of receipt of the petition, the Department must evaluate the petition on its face and in relation to other relevant information and submit to the Commission a written evaluation report with one of the following recommendations:

- Based upon the information contained in the petition, there is insufficient information to indicate that the petitioned action may be warranted, and the petition should be rejected; or
- Based upon the information contained in the petition, there is sufficient information to indicate that the petitioned action may be warranted, and the petition should be accepted, and the status of the species evaluated by the Department.

1.2 Petition History

On 23 July 2018 the Karuk Tribe and Salmon River Restoration Council submitted a petition to the Commission to classify the Upper Klamath-Trinity Rivers (UKTR) spring Chinook Salmon (*Oncorhynchus tshawytscha*) as a separate Evolutionarily Significant Unit (ESU) and to list it as endangered under the CESA. The Commission reviewed the petition for completeness, and pursuant to Section 2073 of the California Fish and Game Code, referred the petition to the Department on 2 August 2018 for evaluation. The Commission gave public notice of receipt of the petition on 17 August 2018. The Department requested a 30-day extension on the 90-day review period on 5 October 2018 which was granted by the Commission at its 17 October 2018 meeting in Fresno, California.

The Department evaluated the scientific information presented in the Petition as well as other relevant information possessed by the Department at the time of review. The Department did not receive any information from the public during the Petition Evaluation period pursuant to Fish and Game Code Section 2073.4. Pursuant to Fish and Game Code Section 2072.3 and Section 670.1, subdivision (d)(1), of Title 14 of the California Code of Regulations, the Department evaluated whether the Petition includes sufficient scientific information regarding each of the following petition components to indicate that the petitioned action may be warranted:

- population trend,
- range,
- distribution,
- abundance,
- life history,
- kind of habitat necessary for survival,
- factors affecting ability to survive and reproduce,
- degree and immediacy of threat,
- impacts of existing management,
- suggestions for future management,
- availability and sources of information, and
- a detailed distribution map.

On 8 November 2018, the Department transmitted ~~the~~ its evaluation, entitled *Evaluation of the petition From the Karuk Tribe and the Salmon River Restoration Council to List Upper Klamath Trinity River Spring Chinook Salmon (Oncorhynchus tshawytscha) as Threatened or Endangered,* to the Commission. The Department found that, based upon the information contained in the petition, there was sufficient evidence to indicate that the petitioned action may be warranted, and recommended that the Commission accept the petition (CDFW 2018b). The Commission received the Department’s evaluation at its 12 – 13 December 2018 meeting in Oceanside, California. At its scheduled public meeting on 6 February 2019 in Sacramento, California, the

Commented [AC31]: Changes made by Christian Smith

Commission considered the Petition, the Department’s evaluation and recommendation, and the comments received. The Commission found that sufficient information existed to indicate the petitioned action may be warranted and accepted the Petition for consideration. Upon publication of the Commission’s notice of its findings, UKTR spring Chinook Salmon was designated a candidate species on 22 February 2019 (California Regulatory Register Notice 2019, 8-Z, 22 February 2019) The Commission referred the petition to the Department on 6 February 2019 with direction to prepare a status review. The Department requested a six-month extension for completion of the status review, which was granted on 12 June 2019 at the Commission’s regularly scheduled meeting in Redding, California.

1.4 Department Review

This report contains the results of the Department’s review and its recommendations to the Commission regarding this petition. The purpose of this status review is to fulfill the mandate as required by Fish and Game Code Section 2074.6 and to provide the Commission with the most current, scientifically-based information available on the status of UKTR spring Chinook Salmon in California, and to serve as the basis for the Department’s recommendation to the Commission. This status review is based on the best scientific information available. It also contains the Department’s recommendation on whether the petitioned action is warranted. Further, this status review identifies habitat that may be essential to the continued existence of the species and suggests prudent management and restoration actions.

A draft version of this document was subjected to independent external peer review by a group of anonymous qualified experts. Comments from external peer reviewers are contained in Appendix D.

1.5 Previous UKTR Spring Chinook Salmon Listing Actions and Reviews

1.5.1 State of California Listing Actions

There have been no previous listing actions for UKTR spring Chinook Salmon under CESA. However, UKTR spring Chinook Salmon are on the list of California Species of Special Concern (Moyle et al. 2015).

1.5.2 Federal Listing Actions

In 2011, the Center for Biological Diversity submitted an Endangered Species Act (ESA) listing petition to National Marine Fisheries Service (NMFS) to list UKTR spring Chinook Salmon (called UKTSC in that petition) as endangered based on declines in abundance and distribution. After review, NMFS found that the listing of UKTR spring Chinook Salmon was not warranted. The petition was denied based on the finding that UKTR spring Chinook Salmon ~~are not~~were not considered genetically distinct from UKTR fall Chinook Salmon; the two ecotypes ~~are~~ were considered genetically similar, together forming a single Evolutionarily Significant Unit (ESU).

Commented [MS32]: See comments throughout. The previous Federal finding concluded that UKTR spring Chinook were not genetically distinct from UKTR fall Chinook, but there is now broad scientific agreement that there are distinct and important adaptive genetic differences between UKTR spring and fall Chinook (Ford et al. 2020). I suggest changing the verb tense to reflect: 1) that this finding occurred in the past; 2) that the best available science now shows this interpretation to be incorrect; and 3) to avoid the perception that these conclusions are factual in light of the above.

Commented [AC33]: Changes made by Matt Sloat

Further, the combined Chinook Salmon populations in the Upper Klamath-Trinity basins were found to be relatively robust, despite declines in the spring ecotype. NMFS regards the UKTR spring Chinook Salmon as a life-history variant evolved from polyphyletic origins that is capable of recovery over time from existing genetic stocks.

Commented [MS34]: Unless, NMFS continues to regard spring Chinook migrations to have evolved from polyphyletic origins, this should be changed to the past tense ('regarded"). There is now broad scientific agreement that spring Chinook salmon migrations did not evolve from polyphyletic origins; spring Chinook migrations did not arise from independently via new mutations from the genomic background of fall Chinook in each watershed (Ford et al. 2020)

In 2017, the Karuk Tribe and Salmon River Restoration Council petitioned NMFS to reconsider its decision and list the UKTR spring Chinook Salmon as endangered. The results of the most recent NMFS review are not yet published at the time of this CESA status review.

1.5.3 Other Independent Status Evaluations

The Department reviewed other independent UKTR spring Chinook Salmon status evaluations from Moyle et al. (2008, 2011, 2015) and Katz et al. (2012). In these independent reviews, the authors chose to analyze the status of UKTR spring Chinook Salmon as if they constituted a distinct ESU. A 2008 status review commissioned by CalTrout (Moyle et al. 2008) evaluated existing species data and "population trends" for UKTR spring Chinook Salmon and concluded that, although there were no obvious short-term (last 20 years) trends, extirpation is a distinct possibility due to small population sizes. UKTR spring Chinook Salmon life history, which includes adults spending an extended period in fresh water where anthropogenic threats are greatest, makes UKTR spring Chinook Salmon more susceptible than UKTR fall Chinook Salmon to these factors. Moyle et al. (2008) attributes the current status of UKTR spring Chinook Salmon to dams, logging, mining, rural development, harvest, hatcheries, and disease. Without action, the authors warn that warming temperatures caused by climate change would likely lead to extinction. One conservation recommendation offered in this assessment was to declare UKTR spring Chinook Salmon a Distinct Population Segment (DPS) and list it as a threatened species under both ESA and CESA. Other recommendations included dam removal and improved habitat and hatchery management.

Commented [MOU35]: I think it would be important to mention that this evaluation, as I recall, is based upon a survey of "expert opinion" rather than any quantitative assessment of population abundance trends, habitat threats, etc. The above approach could be highly biased because it is based upon expert opinion. Thus, this assessment is not objective nor repeatable. Given these concerns, CDFW may wish remove these studies from this report and instead focus on analyses that follow standard scientific principles. At a minimum, the caveats of the analysis should be mentioned and the findings treated with caution.

In Moyle et al.'s (2011) assessment of native fishes in California, the authors evaluated 129 freshwater and anadromous fish "species" (as defined by the authors) and scored their status based on seven criteria: area occupied, estimated adult abundance, dependence on human intervention for persistence, physiological tolerance, genetic diversity, vulnerability to climate change, and anthropogenic threats. Because the evaluation methods needed to be comparable across diverse taxa with different life histories and levels of information, the scale scoring system used is not as detailed as the analysis the Department uses to inform a CESA status review. In this evaluation, UKTR spring Chinook Salmon scored the lowest of any Chinook Salmon in California, which the authors state is roughly equivalent to the IUCN "endangered" threat level (Moyle et al. 2011). This analysis was used to update the Department's Fish Species of Special Concern in California (Moyle et al. 2015), which described the analysis used in Moyle et al. (2011) and also rated anthropogenic factors limiting or potentially limiting the viability of UKTR spring Chinook Salmon. Factors rated "High" (i.e., strong contribution to declines and poor status) included blockage by major dams and hatcheries. Factors rated "Medium" included agriculture and grazing, mining, transportation, recreation, and harvest. Management actions recommended as a result of this evaluation included removing mainstem Klamath River dams, restoring cold-water refugia on the Shasta River, managing the Salmon River as a refuge for UKTR spring Chinook Salmon and summer steelhead, investigating hatchery impacts, improved habitat restoration to mitigate impacts from roads and logging, and harvest recommendations (Moyle et al. 2015).

Commented [MOU36]: Same as above…

Katz et al. (2012) also analyzed some of the species considered in Moyle et al. (2011). The authors used a similar scaling protocol to categorize risk for 32 taxa of California native fishes. Each group received a composite score ranging from 1 (highest risk of extinction or extirpation) to 5 (reasonably stable at this time). Of the 32 taxa considered, 78% were judged likely to become extinct or extirpated within 100 years. UKTR spring Chinook Salmon were evaluated as a separate species, receiving a high-risk score of 1.6.

Commented [MOU37]: I am not familiar with this effort but seems to fall under the same comments as above. Obtaining expert opinion is not valid because the sample of individuals used to draw inference does not represent a probability-based sampling strategy.

2. Biology

2.1 Species Characteristics

Chinook Salmon are semelparous, anadromous, salmonid fishes native to fresh and ocean waters of the North Pacific Rim. Although among the least abundant of all the Pacific salmonids, Chinook Salmon show the greatest life-history diversity and geographic range (Riddell et al. 2018). They are the largest of the Pacific salmon genus *Oncorhynchus*, with adults in northern waters growing as large as 45 kg (99 lbs). The name Chinook refers to the collective Chinookan Native American Tribes of the Pacific Northwest. The species is also known by the common names King Salmon, Tyee, and Quinnat Salmon.

Commented [MOU38]: Interesting, I didn't realize that was the case…

In this status review, the Department uses the common name Upper Klamath and Trinity Rivers spring Chinook Salmon (abbreviated UKTR spring Chinook Salmon) for the early-migrating Chinook Salmon ecotype in the Klamath basin that is the focus of the petition. Other common names for UKTR spring Chinook Salmon include Klamath Trinity spring Chinook, Klamath Trinity spring-run Chinook, and Upper Klamath-Trinity River spring-run Chinook. The name "UKTR Chinook Salmon" is used to indicate the larger UKTR Chinook Salmon ESU containing both UKTR spring Chinook Salmon and UKTR fall Chinook Salmon ecotypes.

Spawning Chinook Salmon are distinguished by their large size, presence of small dark spots visible on both lobes of the caudal fin (also on head and back), and dark pigment at the base of the teeth. Chinook Salmon have a streamlined, fusiform, laterally compressed body shape. The species is characterized by having a large number (>100) of pyloric caeca (McPhail and Lindsey 1970; Hart 1973).

Sea-run Chinook Salmon are dark green to blue-black on their heads and back and silvery to white on the sides and belly. Body color changes to an olive-brown, red, or purplish color during spawning. Males are frequently darker than females and spawning males have a kyped jaw. The anal fin has a white leading edge not set off with a dark pigment line as in Coho Salmon.

Fry and parr are primarily distinguished by large oval spots (parr marks) extending well below the lateral line. However, juvenile characteristics are highly variable and reliable identification is often based on counts of pyloric caeca and meristic traits (e.g., numbers of scales, fin rays, gill rakers).

There are two distinct groups of Chinook Salmon whose adult migration occurs in the spring in California: Central Valley spring-run Chinook Salmon (comprising its own ESU), and Upper Klamath-Trinity Rivers (UKTR) spring Chinook Salmon (a part of the UKTR Chinook Salmon ESU along with UKTR fall Chinook Salmon). The two California ESUs containing spring-returning fish are widely separated spatially—one found in the Central Valley and the other on the North

Coast. The two ESUs are also genetically distant from one another (see discussion in *Section 2.6 Genetics and Genomics and Figure 2.10*).

Additional information on species characteristics can be found in Moyle (1976); Scott and Crossman (1973); Wydoski and Whitney (1979); Morrow (1980); Eschmeyer et al. (1983); Page and Burr (1991).

2.2 Life History and Unique Characteristics

Spawning adult UKTR spring Chinook Salmon enter the Klamath estuary in the spring and summer, from March through July. Proportions of grilse in the three extant UKTR spring geographic locations appear to be moderate to low (Table 2.1). The peak of the spawning migration is May through early June (Moffett and Smith 1950, Myers et al. 1998). In the past, a Klamath River summer Chinook Salmon run (July and August) was described by Snyder (1931). UKTR spring Chinook Salmon in the Salmon River spawn from mid-September to late-October in the Salmon River and from September through early November in the South Fork Trinity River (Stillwater Sciences 2009).

Table 2.1. Proportions of UKTR spring Chinook Salmon grilse observed in the Salmon River, South Fork (SF) Trinity River, Klamath River tributaries, and Trinity River tributaries.

	Salmon River	SF Trinity River	Klamath River tributaries	Trinity River tributaries
Years	1995-2019	1992-2018	1981-2018	1980-2018
Grilse Proportion (average)	0.14	0.12	0.17	0.21
min	0.02	0.01	0.00	0.00
max	0.28	0.45	1.00	0.65

Figure 2.1 shows a generalized life-history for UKTR spring Chinook Salmon. Adult migrants enter fresh water with incompletely developed gonads, holding for 2 – 4 months in cold water prior to spawning. Moffett and Smith (1950) noted that adult migration through the Trinity River is rapid, occurring day and night, with a peak two hours after sunset. Fish that enter TRH between September 3 and October 15 are categorized as UKTR spring Chinook Salmon. Many UKTR spring Chinook Salmon hold just below the hatchery prior to this in June – August; however, the UKTR spring Chinook Salmon start date may be artificially affected by hatchery operations. Barnhardt (1994) and NRC (2004) reported that most of the fish entering late in the season during their studies were of hatchery origin. The migration of Trinity River UKTR spring Chinook Salmon has been reported to extend into October (Leidy and Leidy 1984);

Commented [MOU39]: I think it might be worthwhile to work on this section a little bit to clarify given the important of entry-date to genomic associations. What is the range of potential entry dates versus when the bulk of fish enter the river? Also, the spawn dates are mentioned here are important to concepts for temporal reproductive isolation so it would be clarify the difference. Off the top of my head, entry dates are primarily:
1 May to 31 July: spring-run
1 August to early November (?): fall-run

Spawn dates are TRH:
Early-sept to mid-Oct: spring
Mid-Oct to early-Dec: fall

The Yurok Tribe has years of at-entry gill-net fishing data on this. They could tell you when they start catching fish…

Hearsey and Kinziger () provide a citation for at-entry dates.

Maybe a table of entry-dates and spawn-dates as portrayed in different studies would be helpful?

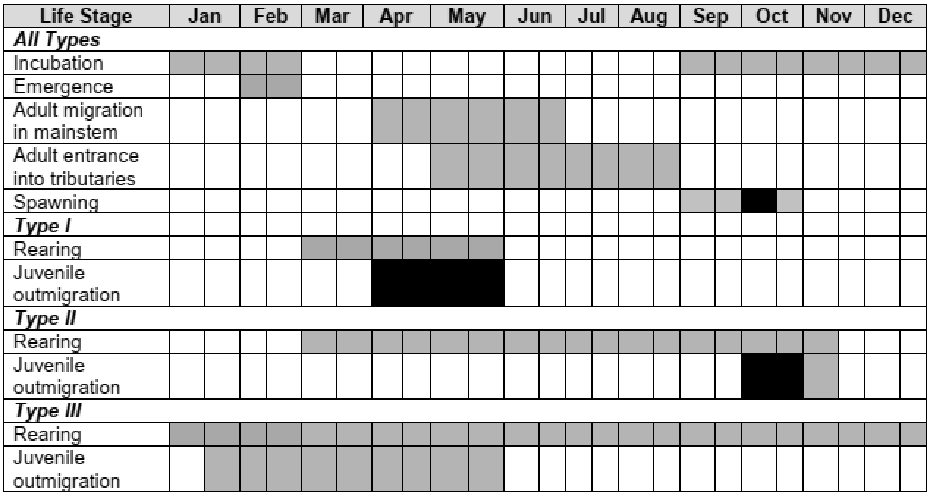
Commented [MOU40]: This is data from Lewiston on the Trinity River – not estuary correct?

Commented [MOU41]: I think that TRH has often started spawning operations the week after labor day, so early September.

Formatted Table

Commented [MOU42]: Do you mean "initiation of freshwater migration"?

Commented [MOU43]: Where at-entry to the Klamath River or at TRH?



Life Stage	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
All Types																								
Incubation	▨	▨	▨	▨													▨	▨	▨	▨	▨	▨	▨	▨
Emergence			▨	▨																				
Adult migration in mainstem							▨	▨	▨	▨	▨	▨												
Adult entrance into tributaries									▨	▨	▨	▨	▨	▨	▨	▨								
Spawning																	▨	▨	■	▨				
Type I																								
Rearing					▨	▨	▨	▨	▨	▨														
Juvenile outmigration							■	■	■	■														
Type II																								
Rearing					▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨			
Juvenile outmigration																			■	■	▨			
Type III																								
Rearing	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Juvenile outmigration		▨	▨	▨	▨	▨	▨	▨	▨	▨														

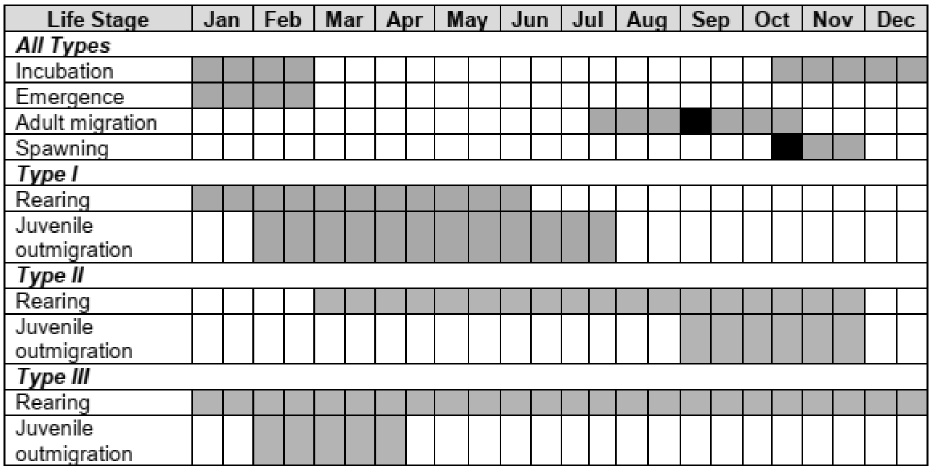
Figure 2.1. Life-history of UKTR spring Chinook Salmon in the Klamath River. Type I: ocean entry at age 0 in early spring, Type II: ocean entry at age 0 in fall or early winter, and Type III: ocean entry at age 1 in spring. Gray: presence in the river; Black: peak activity. From: SWRCB 2018.

however, it is unclear whether these late-arriving fish spawn with other UKTR spring Chinook Salmon. Since this was only observed in the Trinity River, these late arrivals may represent spring/fall hybrids of Trinity River Hatchery (TRH) origin.

Hatching occurs 40 – 60 days after egg deposition, and alevins remain in natal gravels for 4 – 6 weeks. Both hatching and emergence timing are dependent on water temperature. UKTR spring Chinook Salmon fry emergence occurs in early winter (Leidy and Leidy 1984), extending to late May (Olsen 1996). Prior to construction of Lewiston Dam, fry emergence occurred as early as January. Leidy and Leidy (1984) found that emergence begins as early as November in the Trinity River, and December through February in the Klamath River. Juvenile emigration occurs February through mid-June (Leidy and Leidy 1984).

In contrast to some more northerly (e.g., Columbia River) spring Chinook populations, UKTR spring Chinook Salmon mostly exhibit an “ocean-type,” and only rarely a “stream-type” life-history pattern (Healey 1991, Dean 1995). Stream-type juveniles spend one or more years in their natal rivers prior to migration to the ocean. Ocean-type juveniles are characterized by river outmigration within their first year and an extended estuary residence prior to ocean entry. The ocean-type life history is associated with Chinook Salmon in smaller coastal rivers and lower reaches of larger river systems. Stream-type fish are typically found in headwaters and more northern basins (Healey 1991). Snyder (1931) examined 35 adult UKTR Chinook Salmon scale samples, 83% of which showed an ocean-type growth pattern.

Three rearing types have been identified in UKTR Chinook Salmon (Sullivan 1989): Type I: ocean entry at age 0 in early spring, Type II: ocean entry at age 0 in fall or early winter, and Type III: ocean entry at age 1 in spring. Scheiff et al. (2001) found that 63% of natural Chinook Salmon outmigrants emigrated as Type I, 37% as Type II, and less than 1% as Type III. Wild UKTR spring Chinook Salmon from the Salmon River appear to primarily express a Type II life history (Olson 1996; Sartori 2006). A small number of fish employ the Type III life history, although it does not appear to be as common. For UKTR fall Chinook Salmon in the Klamath River, upstream spawning migration through the estuary and Lower Klamath River peaks in early September and continues through late October (Moyle 2002; FERC 2007; Strange 2012; Figure 2.2). Fall Chinook spawning peaks in late October to early November. Fry emergence extends from early February through early April (Stillwater Sciences 2009), although emergence timing varies by year and tributary depending on temperature.



Life Stage	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
All Types																								
Incubation	▨	▨	▨	▨																▨	▨	▨	▨	▨
Emergence	▨	▨	▨	▨																				
Adult migration														▨	▨	▨	■	▨	▨	▨				
Spawning																				■	▨	▨		
Type I																								
Rearing	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨													
Juvenile outmigration			▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨										
Type II																								
Rearing					▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
Juvenile outmigration																	▨	▨	▨	▨	▨	▨		
Type III																								
Rearing	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Juvenile outmigration			▨	▨	▨	▨																		

Figure 2.2. Life-history of UKTR fall Chinook Salmon in the Klamath River. Type 1: ocean entry at age 0 in early spring, Type 2: ocean entry at age 0 in fall or early winter, and Type 3: ocean entry at age 1 in spring. Gray: presence in the river; Black: peak activity. From: SWRCB 2018.

2.3 Taxonomy and Systematics

Chinook Salmon *Oncorhynchus tshawytscha* are one of nine species of the genus *Oncorhynchus*. The genus *Oncorhynchus* is in the family Salmonidae (salmon, trout, and chars) and the Class Osteichthys OsteichthyesOsteichthys ~~Osteichthys~~ (bony fishes). Figure 2.3 shows a complete taxonomic hierarchy for the species. Chinook Salmon are most closely related to and are the sister taxon of

Commented [MOU44]: Check spelling

Commented [AC45]: Changes by Christian Smith

Coho Salmon *(Oncorhynchus kisutch)*~~, forming a subgroup of the genus~~ (Figures 2.4, 2.5). The close relationship of Coho and Chinook salmon, and their separation from other salmon species is consistently shown in phylogenetic studies (e.g., Stearley and Smith 1993; Thomas et al. 1986).

Commented [AC46]: Changes by Microsoft Office User

There are numerous non-taxonomic units of Chinook Salmon in California. The most common consist of "runs" of fish returning to a specific drainage (e.g., "the Klamath River") and/or at a specific time (e.g., "spring")[1], and Evolutionarily Significant Units (ESUs) (Distinct Population Segments [DPSs] for Pacific Salmon; see below). The currently recognized ESUs of California Chinook Salmon and their listing status under both state and federal law are shown in Table 2.2.

Kingdom Animalia

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- **Kingdom** Animalia
  - **Subkingdom** Bilateria
    - **Infrakingdom** Deuterostomia
      - **Phylum** Chordata
        - **Subphylum** Vertebrata
          - **Infraphylum** Gnathostomata
            - **Superclass** Actinopterygii
              - **Class** Teleostei
                - **Superorder** Protacanthopterygii
                  - **Order** Salmoniformes
                    - **Family** Salmonidae
                      - **Subfamily** Salmoninae
                        - **Genus** *Oncorhynchus* (Suckley, 1861) Pacific salmon
                          - **Species** *Oncorhynchus tshawytscha* (Walbaum in Artedi 1792)

Figure 2.3. Chinook Salmon Taxonomy. Source: *Integrated Taxonomic Information System* (ITIS) Standard Report [2].

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[1] "Runs" in California are generally defined geographically and/or temporally. Sometimes runs are synonymous with "ecotypes" and sometimes they are not.

[2] Available online (accessed 8 June 2020): https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=161980#null

Table 2.2. Evolutionarily significant units (ESUs) of Chinook Salmon in California, including ESA/CESA listing status.

Evolutionarily Significant Units	ESA/CESA Listing Status
Southern Oregon and Northern California Coastal Chinook Salmon	Not listed/Not listed
Upper Klamath Trinity Rivers Chinook Salmon	Not listed/Not listed
California Coastal Chinook Salmon	Threatened/Not listed
Central Valley fall-late fall Chinook Salmon	Candidate/Not listed
Central Valley spring-run Chinook Salmon	Threatened/Threatened
Central Valley winter-run Chinook Salmon	Endangered/Endangered

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Commented [SC47]: Should this be "Not-listed"?

The CESA listing petition addressed in this status review references UKTR spring Chinook Salmon, which are ~~generally~~ currently recognized as a part of the UKTR Chinook Salmon ESU (e.g., Myers et al. 1998, Williams et al. 2013). In addition to UKTR spring Chinook Salmon, the greater UKTR Chinook Salmon ESU contains a fall migrating ecotype. The spring and fall ecotypes are not completely reproductively isolated over a substantial portion of their spawning distribution. Snyder (1931) and Moffet and Smith (1950) refer to a summer run ecotype, and a late-fall ecotype was also believed to have been present historically but is thought to have been extirpated.

Commented [MS48]: I suggest changing "generally" to "currently".

Commented [MS49]: This sentence needs more context to be completely accurate. Spring and fall Chinook do interbreed, but they typically exhibit significant spatio-temporal reproductive segregation. My suggestion is to add the word "completely" here to be more accurate.

Commented [MOU50]: Interesting, is there a citation for this. I'd like to know more…

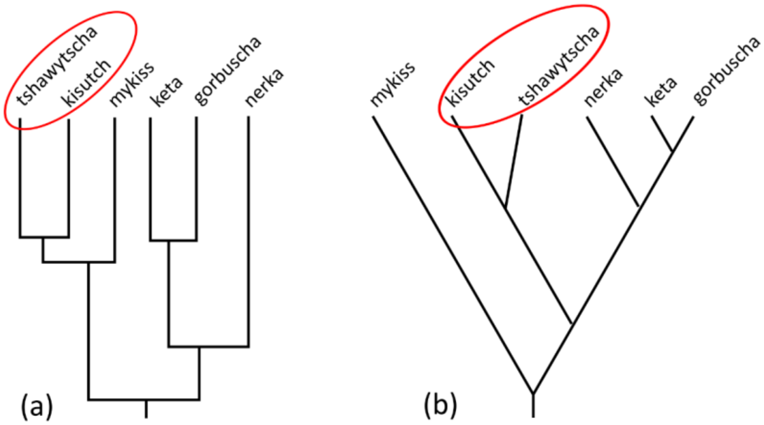


Figure 2.4. Unweighted pair group method with arithmetic mean (UPGMA) Phenogram (a) and Cladogram (b) of mitochondrial DNA data showing genetic relationships of Pacific salmon species. From: Thomas et al 1986, as cited in Stearley and Smith 1993.

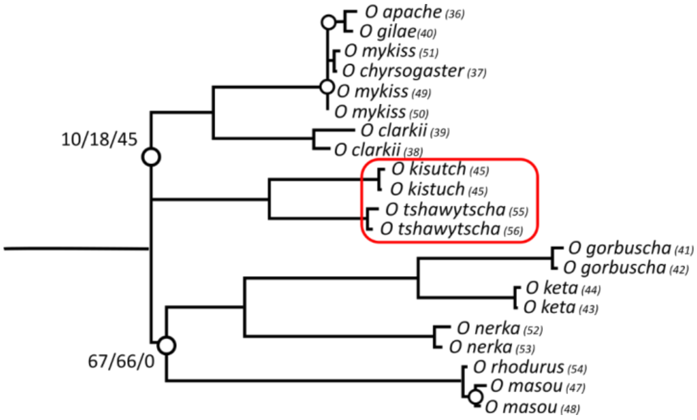


Figure 2.5. Unrooted maximum likelihood phylogram based on the cytochromes data set showing the relationships among members of genus *Oncorhynchus* and close relationship of *O. tshawytscha* and *O. kisutch*. Derived from: Figure 1 in Crête-Lafreniè et al. 2012.

2.4 The Evolutionarily Significant Unit Concept

The federal ESA defines species to include "any subspecies of fish or wildlife or plants, and any distinct population segment (DPS) of any species of vertebrate fish or wildlife which interbreeds when mature." To be classified as a DPS, a population segment must be both discrete (geographically separated, or physiologically, ecologically, behaviorally distinct) and significant to the species (61 FR 4722). Status of a population segment is only considered after determining both discreteness and significance.

Commented [MS51]: The ESA defines species in the legal sense 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." As applied to Pacific salmon, a population (or group of populations) is considered "distinct'" (and hence a "species") for purposes of the ESA if it represents an evolutionarily significant unit (ESU) of the biological species (Waples 1991).
A population (or group of populations) must satisfy two criteria to be considered an ESU: **1)** It must be substantially reproductively isolated from other conspecific population units, and **2)** It must represent an important component in the evolutionary legacy of the species (Waples 1991).

The NMFS developed the ESU concept to provide a consistent, meaningful, and appropriately restrictive policy for determining whether a given sub-taxonomic group of Pacific salmon fit the definition of a DPS (Moritz 1994; Waples 1991a). Waples (1991a) defines the ESU as follows: "A population (or group of populations) will be considered distinct (and hence a 'species') for purposes of the ESA if it represents an ESU of the biological species." Two criteria must be met for a taxon/non-taxon to be considered an ESU: 1) it must be *reproductively isolated* from other conspecific population units, and 2) it must represent *an important component of the evolutionary legacy of the species* (Waples 1991a). This ESU definition provides a way to specifically address the discreetness and significance criteria required to classify a Pacific salmon population segment as a DPS.

Commented [MS52]: The language in Waples 1991a is "substantially reproductively isolated". Waples is very clear that reproductive isolation does not have to be absolute, it just must be strong enough to permit evolutionarily important differences to accrue. Because this is one of the main criteria that defines a species in the legal sense, it is important to be clear on this point and faithful to the original definition.

In past CESA status reviews for California salmon, the Department has recommended, and the Commission has found, federally-recognized ESUs to be an appropriate biological and geographic basis for listing California salmon stocks, e.g., Sacramento River winter-run Chinook

Salmon ESU (CESA endangered), Sacramento River spring-run Chinook Salmon ESU (CESA threatened), Southern Oregon-Northern California Coast Coho Salmon ESU (CESA threatened), and Central California Coast Coho Salmon ESU (CESA endangered)(CDFG 1998, 2002).

The Department agrees that the current delineation of the UKTR Chinook Salmon ESU and other surrounding Chinook ESUs depict the most likely boundaries of largely reproductively isolated and ecologically divergent groups of Chinook Salmon populations in the Klamath basin. The ESU approach to delineation of listing units is consistent with previous state and federal salmon listings, and the federal approach to species evaluation~~, and the generally accepted biological criterion that a species is “a group of interbreeding organisms that is reproductively isolated from other such groups” (Mayr 1966).~~

The petition (Karuk Tribe and Salmon River Restoration Council 2018) requests that the Commission classify the UKTR spring Chinook Salmon as a separate ESU and list it as endangered under CESA. The petitioners go on to describe the federal listing request that was the subject of Williams et al. (2011), noting that, at that time, ESA listing was denied because evidence did not warrant reclassification of UKTR spring Chinook Salmon as its own ESU. The petition then claims that recent genetic evidence (a genomic association with early run-timing described in Prince et al. 2017) demonstrates sufficient differentiation between UKTR spring and fall Chinook Salmon to classify UKTR spring Chinook Salmon as a separate ESU. On this basis, a new ESA petition was submitted November 2, 2017. The petitioners assert that evidence supporting a federal listing would also support listing under CESA.

As of the release date of this status review, the NMFS evaluation of the Klamath-Trinity Chinook ESU structure groups UKTR spring Chinook Salmon along with UKTR fall Chinook Salmon as a single ESU: UKTR Chinook Salmon ESU. This ESU was first delineated in Myers et al. (1998) and supported in subsequent federal reviews (Williams et al. 2011, 2013). In both instances, when responding to the relevant listing petition, NMFS did not list the combined UKTR Chinook Salmon ESU due to the relative abundance of the combined spring and fall ecotypes. Further, NMFS did not list the spring ecotype as a separate ESU because of the lack of reproductive isolation of spring and fall Chinook in the basin. The Department agrees with NMFS that the UKTR Chinook Salmon ESU designation, comprised of both spring and fall elements, is a valid and justifiable construct from both biological and management perspectives.

It is not clear at this time how NMFS will use genomics data of the type described in Prince et al. (2017) in future ESU delineations and the ESA listing process (Pearse 2016; Coates et al. 2018; Fraser and Bernatchez 2001); however, use of a single genomic association to define an ESU may not be appropriate for several technical reasons. (See Waples and Lindley 2018 and Waples et al. 2020 for a detailed discussion of the issues, and *Section 2.6 Genetics and Genomics* of this document for a full discussion.)

This CESA status review responds directly to the geographic range and stocks specified in the petition to list. The petition requests that the Commission list UKTR spring Chinook Salmon

Commented [MS53]: Biologistis still struggle with the **biological** definition of a species and this definition is less generally accepted than implied here (e.g., Dobzhansky 1935; Hey 2001). The ESU approach, however, provides clear criteria for the **legal** definition of a species. Because the legal definition under the ESA provides well-articulated criteria, but debate over the biological species problem continues, I suggest not conflating them here.

Dobzhansky, T., 1935. A critique of the species concept in biology. *Philosophy of Science*, *2*(3), pp.344-355.

Hey, J., 2001. The mind of the species problem. *Trends in Ecology & Evolution*, *16*(7), pp.326-329.

Commented [MOU54]: It has been a few years since I’ve read these documents but I thought that a key component of the NMFS argument was that UKTR spring and fall Chinook salmon didn’t represent independent evolutionary lineages but instead evidence via a process of parallel evolution.

Commented [MS55]: In my read of Waples (1991) and the standards of the ESA as they apply to Pacific Salmon, the primary consideration here should be whether genetic differences identified by Prince et al. (2017), as well as Thompson et al. (2019), and others represent an important component in the evolutionary legacy of the species. The genetic architecture underlying a potentially evolutionarily significant legacy should be secondary.

The existing ESA framework can accommodate new genomics data of the type described in Prince et al. (2017) in combination with other relevant information. I would encourage the Department to use this new information in a manner that is consistent with the ESA standards.

Commented [MOU56]: It is important to note that the recent discover of a genetic region associated with run-timing didn’t change our fundamental understanding about the evolutionary history of spring- and fall-run Chinook salmon. In fact, the genomic analysis continue to support the hypothesis of parallel evolution.

native to the Klamath and Trinity Rivers as endangered based on information the petitioners argue support its delineation into an ESU separate from the currently recognized UKTR Chinook Salmon ESU. Therefore, this status review and recommendations focus on information for all quasi-populations (also called “population components” in this review) of UKTR spring Chinook Salmon, including hatchery-origin fish in the Klamath and Trinity Rivers.

The Department does not recommend the UKTR spring Chinook Salmon ecotype be considered a subspecies under CESA under the petitioned basis that it qualifies as an independent ESU. However, in order to provide a more complete review, this status review considers (to the extent possible) the status of the combined spring and fall ecotypes that comprise the UKTR Chinook Salmon ESU. In this review the Department considers the UKTR spring Chinook Salmon to be an ecotype of the combined (spring plus fall) UKTR Chinook Salmon ESU and recommends the Commission look to the combined UKTR Chinook Salmon ESU as the proper level at which to ultimately decide status.

2.6 Genetics and Genomics

2.6.1 Role of Genetics and Genomics in Evaluating Chinook Salmon Population Structure

Most genetic studies have used neutral genetic markers (e.g., microsatellite DNA) to quantify the population structure of Chinook Salmon in the Klamath basin and surrounding areas. Neutral markers are not specifically associated with a particular life-history trait and are assumed not to be under direct selection. This class of genetic marker has been, and continues to be, used to investigate and define salmonid listing units and population structure in California and across the Pacific Northwest (e.g. Myers et al. 1998; Banks and Barton 1999; Banks et al. 2000a, 2000b; Kinziger et al. 2013; Williams et al. 2011).~~).~~ More recently, the advent and rapid development of “adaptive” genetic markers has sparked debate within the fisheries genetics community. There is substantial controversy in the scientific community about the use of adaptive genetic markers for defining conservation units. Waples and Lindley (2018), Pearse (2016), Shafer et al. (2015), and Allendorf et al. (2010) provide reviews and cautions. On the one hand, adaptive genetic markers provide putative associations with specific life-history characteristics: the “genetic type” infers information about a ~~specific trait~~phenotype of interest. In the case of UKTR spring Chinook Salmon, the single associated trait of interest is migration timing. Alternatively, neutral markers have been used successfully for decades to delineate populations and ESUs based on more or less reproductively isolated lineages. Importantly, analyses based on neutral and adaptive genetic markers may yield different answers to the question of whether a trait is monophyletic or polyphyletic, yielding conflicting conclusions regarding conservation unit delineation..

2.6.1.1 Monophyletic vs. Polyphyletic Evolutionary History

Determination of what constitutes a genetically distinct unit from an evolutionary genetics perspective depends on whether a stock, population, or group of populations is sufficiently

Commented [MOU57]: I think it would be important to highlight that neutral markers are the standard for tracking species evolutionary history.

Commented [MS58]: The use of “phenotype” is more accurate here because the genetic type is usually statistically associated with a specific trait that is practical to measure (e.g., river entry timing), but the genotype can be associated with other phenotypic traits that are not always outwardly observable or practical to measure (e.g., physiological and behavioral traits like metabolism, fat storage, gonad development).

Commented [MS59]: This is not accurate. As mentioned in the previous comment, in the case of UKTR spring Chinook, migration timing is the trait that is most practical to measure, so statistical approaches have focused on the association between a genetic marker and this trait. However, there are other multiple other traits of interest that appear necessary to for spring migration timing to be successful. The gene region that has the strongest association with spring Chinook run timing has also been associated with diverse behavior and metabolic processes such as foraging and fat storage that would appear adaptive for a migratory behavior that requires river entry months in advance of spawning, and prolonged periods of fasting during the final stages of maturation.

Commented [MOU60]: I think this statement should be reworked.

We use neutral markers to estimate the genetic relationships and evolutionary history of species (not traits).

Genes may have an evolutionary history that is different that the species history (e.g., gene tree vs species tree).

Commented [MS61]: Perhaps, but in the case of spring Chinook migration timing, there is now a clear understanding that neutral markers do not accurately chronicle the evolution of the alleles responsible for spring Chinook run timing. There is broad scientific agreement that the alleles associated with UKT spring Chinook run timing arose once from a single evolutionary event and cannot be expected to readily re-evolve (Prince et al. 2017; Thompson et al. 2019; Ford et al. 2020).

Commented [SC62]: My most substantial criticism of this draft Status Review is that the concepts of monophyly and polyphyly are invoked in this section in ways that don’t make sense to me. A few sentences appear incorrect, whereas others just seem unclear. In the example of the highlighted sentence, I’m not clear on whether the authors are trying to describe the main difference between using neutral versus adaptive markers for conservation unit delineation, or point out that phylogenies based on single ...

reproductively isolated from others and whether that group displays unique life-history attributes (e.g., run timing) and local adaptation. Uniqueness in an evolutionary genetic sense depends on whether a trait or group has a "monophyletic" as opposed to a "polyphyletic" evolutionary history.

Commented [MOU63]: Evolutionary uniqueness doesn't depend on monophyly for a "trait" but instead the species as a whole must be estimated to monophyletic.

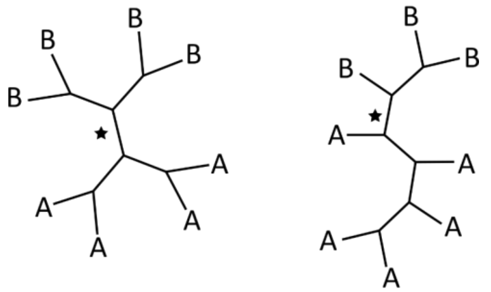
A group that is monophyletic for a given trait is one in which the specific trait type (e.g., migration timing) arose only once in evolutionary history such that all individuals with the trait arose from the same common ancestor (Figure 2.6). Populations with such monophyletic traits, and associated life-history strategies, are considered unique and irreplaceable if lost. On the contrary, if a group's life-history strategy is polyphyletic, then that life-history strategy is judged to have arisen more than once through a process of parallel evolution. Even if lost in one place, the trait could potentially be recovered from existing genetic variation present in other groups in other places, or from existing variation in the same location if environmental conditions improve.

Commented [MOU64]: I think this should be revised.

These figures are trait histories, not species histories.

Commented [SC65]: Whether or not a trait could be recovered from existing variation present in other groups does not depend on whether or not the underlying genetic sequence is monophyletic.

Single evolutionary event



Parallel evolution

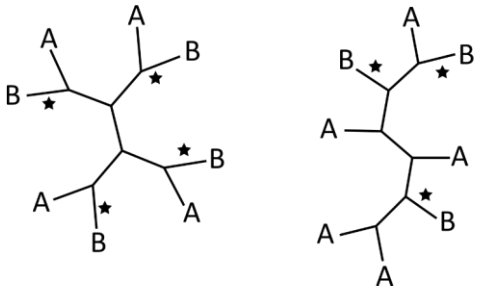


Figure 2.6. Two generalized patterns of life-history trait evolution. A star (★) denotes an evolutionary change. Top: The pattern of genetic/life-history relationships can be explained

by a single episode in which trait B evolved from trait A (or vice versa). Bottom: A minimum of four (left) or three (right) parallel evolutionary changes is required to explain the observed pattern of relationships. From: Waples et al. 2004.

A common method for determining whether a life history strategy is mono- versus polyphyletic is to quantify the degree of genetic difference between populations with alternate life-history traits (in this case the early-migrating spring versus later-migrating fall ecotypes) in comparison to the level of genetic difference of groups with alternate life-history traits among geographic locations where they are found (Waples et al. 2004; Williams et al. 2013). Determining the pattern of genetic variation in terms of trait group and geography determines the level of reproductive isolation exhibited among groups.

Commented [SC66]: ?

Determining whether the proposed listing unit identified by the petitioners exhibits reproductive isolation is an important component of both state and federal status review evaluations (e.g. Waples 1991a, 1995). Information on local adaptation and life-history are also important considerations in evaluating ESU boundaries (Waples 2006). For the petitioned unit and associated life-history strategy to represent an important component of the evolutionary legacy of the species, requires that the group be genetically unique, arose only once, and is thus irreplaceable (i.e., it is monophyletic). This distinction has been consistently used at the federal level to evaluate ESA listing petitions for Pacific Salmonids.

2.6.2 Genetic Studies

There is a long history of genetic analyses of Chinook Salmon populations in the Upper Klamath and Trinity rivers (e.g., Anderson et al. 2019; Thompson et al. 2019; Prince et al. 2017; Kinziger et al. 2008 a, 2008b, 2013). Most studies used protein (i.e., allozymes) variation or neutral genetic markers (e.g., microsatellite DNA) to investigate population genetic relationships among stocks living in the basin and surrounding areas. Some more recent studies (Prince et al. 2017; Thompson et al. 2019; Anderson et al. 2019; Anderson and Garza 2019) used genomic methods to identify a specific gene region associated with early migration timing in Chinook Salmon.

Myers et al. (1998) originally examined genetic differences between UKTR spring and fall Chinook in the Klamath-Trinity using allozymes and hatchery stocks. They found that spring and fall Chinook Salmon from the same location were more similar to one another than they are were to spring and fall Chinook in another location. This is a common pattern of landscape genetic structure called “isolation by distance.” This pattern is interpreted as meaning that genetic structure is based more on geography (i.e., proximity) than other factors like run-timing. From this, Myers et al. (1998) concluded that 1) UKTR spring and fall Chinook comprised ecotypes of a single ESU but acknowledged that 2) hatchery propagation of both runs in the basin over many generations likely blurred genetic distinctions between spring and fall fish through unintentional introgression in the hatcheries and in the wild. They were aware of this issue and recommended that their proposed single ESU should be revised pending future genetic analyses. Allozymes are a genetic marker system based on underlying genetic differences in expressed proteins that has been used extensively since the early days of population genetic analyses; however, it is known that the technique lacks power to detect finer genetic differences discernable using DNA-based marker systems. Allozyme markers were largely replaced by microsatellite DNA loci in population genetics evaluations after approximately the year 2000. Microsatellite DNA-based marker systems have been used in many population genetic studies in various taxa to investigate and define population structure.

Banks et al. (2000a), expanding on a previous study of Klamath basin Chinook Salmon (Banks et al. 1999), found greater genetic distance among some UKTR fall Chinook Salmon populations than among UKTR spring and fall Chinook Salmon populations (Figure 2.7). The authors concluded that geographic origin was more important than life history to the overall structure of Chinook Salmon genetic diversity in the basin. This finding contrasted with genetic diversity structuring observed in California Central Valley Chinook Salmon (Banks et al. 2000b). In that study, Central Valley Chinook Salmon populations clustered primarily according to life-history type (i.e., fall/late fall-run, spring-run, and winter-run) resulting “in a tree that had little in common with the geographic origin of samples despite the greater distance between samples from the Central Valley in comparison to distances between samples of the Klamath and Trinity basin” (Banks et al. 2000b, as cited in Williams et al. 2013).

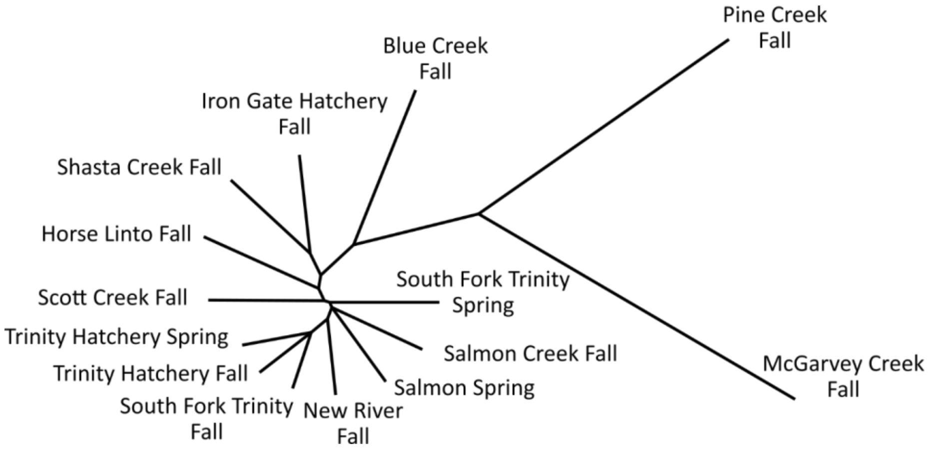


Figure 2.7. Unweighted pair group method with arithmetic mean (UPGMA) phenogram of population samples from UKTR spring and fall Chinook Salmon populations of the Klamath and Trinity basins based on seven microsatellite loci. From: Banks et al. 2000a.

Kinziger et al. (2008a) examined collections from 12 UKTR Chinook Salmon quasi-populations at 17 variable microsatellite loci. The authors examined samples representing all drainages known to have substantial adult Chinook Salmon returns. Collections included both natural-origin and hatchery-origin fish and known spawning areas for both UKTR spring and fall Chinook Salmon. The authors found substantial genetic structure across the basin in four genetically differentiated and geographically separated groups: Upper Basin, Trinity (including spring and fall from the Trinity River Hatchery (TRH) and the South Fork Trinity River), Salmon (containing spring and fall from the Salmon River), and Lower Basin. More importantly, their data indicated that spring- and fall Chinook Salmon life-histories have repeatedly evolved independently (i.e., exhibit a polyphyletic evolutionary history) and in parallel within both the Salmon and Trinity rivers. The authors concluded that UKTR spring and fall Chinook Salmon are not reproductively isolated, unique lineages. This pattern of genetic diversity within the basin was reaffirmed in Kinziger et al. (2013) wherein they analyzed 790 individuals from 10 naturally-spawning and three hatchery populations using 27 microsatellite loci. Similar to their previous study, the authors found a strong pattern of genetic isolation-by-distance, with genetic distance between populations strongly predicted by geographic distance independent of run-timing (Figure 2.8). More significant to this petition, Kinziger et al. (2013) found that UKTR spring and fall Chinook Salmon from the Salmon River exhibited non-significant levels of genetic differentiation and

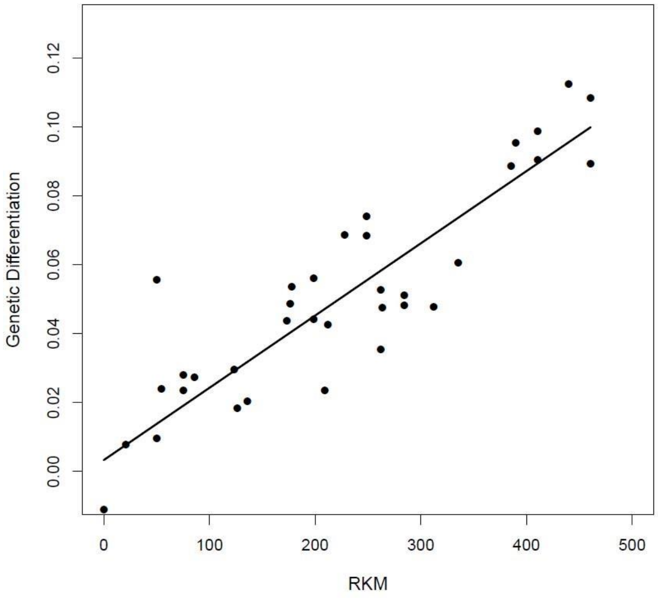


Figure 2.8. Relationship between pairwise genetic differentiation (G'_{ST}) and river distance (RKM) for Klamath River Chinook Salmon above Klamath and Trinity river confluence (excludes Horse Linto Creek) showing pattern of isolation by distance. From: Williams et al. 2013, based on original figure in Kinziger et al. 2013

were nearly indistinguishable genetically. They also confirmed the earlier results of Kinziger et al. (2008a, 2008b) that Trinity River Hatchery UKTR spring and fall Chinook Salmon are extremely closely related and that the two run types are more genetically similar to one another than to any other groups in the basin (Figure 2.9). They also examined UKTR spring and fall Chinook Salmon samples from the South Fork Trinity River and found that they were extremely similar to both each other and to TRH Chinook Salmon, but it was noted that the ability to detect differentiation was limited by small samples.

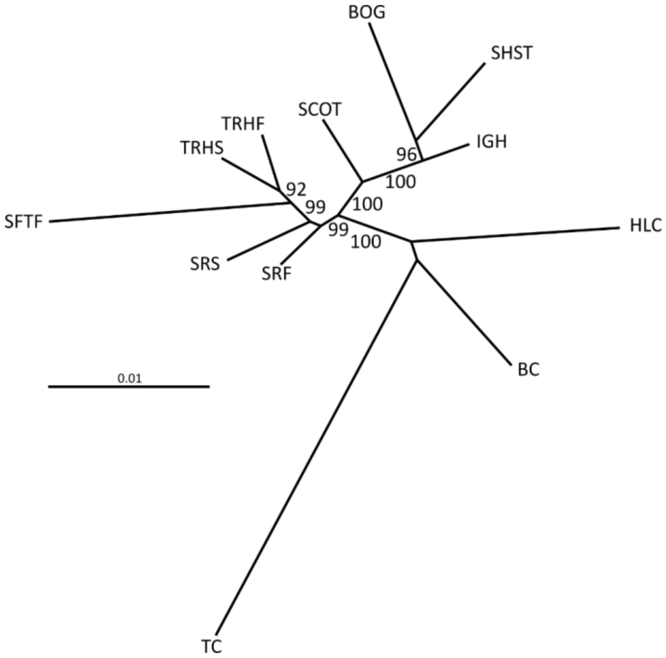


Figure 2.9. Unrooted neighbor-joining tree based on microsatellite DNA data. Branch lengths are equivalent to Cavalli-Sforza genetic distance. Bootstrap support indicated at branch points. Location codes: IGH: Iron Gate Hatchery, BOG: Bogus Creek, SHST: Shasta River, SCOT: Scott River, SRS: Salmon River Spring, SRF: Salmon River Fall, TRHS: Trinity River Hatchery Spring, TRHF: Trinity River Hatchery Fall, SFTF: South Fork Trinity River Fall, HLC: Horse Linto Creek, BC: Blue Creek, TC: Terwer Creek. From: Williams et al. 2013, based on Kinziger et al. 2013.

In summary, the series of studies conducted by Kinziger and colleagues showed that there are greater genetic differences among UKTR Chinook Salmon at different locations within the UKTR system than between the spring and fall migrating life-history types. Additionally, and particularly relevant to this CESA petition, their data suggest that the UKTR spring ecotype arose locally from, and interbreeding with, populations in multiple locations – not from a singular, genetically unique UKTR spring Chinook Salmon ancestor. This pattern clearly implies that migration timing in UKTR Chinook Salmon is polyphyletic – the spring migration-timing ecotype could reemerge from existing UKTR fall Chinook Salmon stock if UKTR spring Chinook Salmon were locally extirpated, and that UKTR spring Chinook Salmon are not genetically unique.

2.6.3 Additional Recent Analyses

Recently, Prince et al. (2017) and Thompson et al. (2019) published genetic studies analyzing UKTR spring and fall Chinook. These studies are prominent elements in support of the CESA listing petition (Karuk Tribe and Salmon River Restoration Council 2018). Rapid advances in genomics, the study of the architecture and function of the entire genome of an organism, and methods able to generate very large data sets, have yielded additional genetic results that are relevant to the petitioned assertions addressed in this status review.

Prince et al. (2017) examined population structure in five coastal California and southern Oregon Chinook Salmon ESUs including UKTR spring and fall Chinook from the Trinity and Salmon rivers. They used approximately 55,000 single nucleotide polymorphism (SNP) genetic markers to evaluate population structure. Similar to the results presented in Kinziger et al. (2008a, 2013), Prince et al. (2017) likewise found that overall population genetic structure was much more affected by geographic location than by run timing. Additionally, using the entire genomic data available to them, the authors found that UKTR spring Chinook Salmon did not demonstrate a monophyletic evolutionary history. The authors further concluded that measurements of genetic differentiation in the multiple Chinook Salmon populations they surveyed were consistent with current ESUs.

The authors also identified and examined a region of the Chinook Salmon genome that has a significant association with run timing, the *GREB1L* region on Chinook chromosome 28, and developed a set of SNP genetic markers in this genomic region. Samples for the Prince et al. (2017)~~is this~~ study were chosen from the early and late extremes of run-timing distribution to represent different (early and late) run-timing groups. They found that there are two forms (i.e., alleles) of DNA in this region corresponding to the spring and fall migration life-histories. They further stated that the two forms of this region are monophyletic, ~~yet~~ are also highly conserved and shared across a broad array of Chinook Salmon populations. Because of this conclusion, the authors assert that, should groups containing the "spring allele" be extirpated, the early migration phenotype could be irretrievably lost. However, importantly, the authors found that while the evolutionary pattern of inheritance looking at a single gene region appeared monophyletic, the pattern looking at the entire genome was polyphyletic.

Prince et al. (2017) also reanalyzed steelhead data from Hess et al. (2016). ~~This~~ Similar to the findings from Hess et al. (2016), Prince et al. (2017)~~This study~~ also found a significant association ~~with~~ between run-timing and *GREB1L*. Heterozygotes were found to migrate at

Commented [MS67]: Please see my extensive comments on this body of research in my written response to this report. There is broad scientific agreement that the findings of Kinzinger et al. and other studies referenced in this section are now known to be incorrect with regard to the evolution of spring Chinook migrations. There is now a clear understanding that neutral markers do not accurately chronicle the evolution of the alleles responsible for spring Chinook run timing. There is broad scientific agreement that the alleles associated with UKT spring Chinook run timing arose once from a single evolutionary event (i.e., are monophyletic) and cannot be expected to readily re-evolve (Prince et al. 2017; Thompson et al. 2019; Ford et al. 2020).

Commented [MS68]: It is unclear to me why this section is not integrated with the section above?

Commented [MS69]: It was a little unclear which study is being referred to here. I assume Prince et al.

Commented [MS70]: This statement is somewhat nonsensical. What Prince et al. found was that overall patterns of genetic relatedness between spring and fall Chinook do not accurately reflect the monophyletic origins of spring Chinook migration timing. This pattern is consistent with their being a degree of reproductive connectivity between fall and spring Chinook, but very strong selection on the alleles responsible for successful spring migrations. For example, spring and fall Chinook from the same watershed can share genetic similarities at many loci and still be genetically distinct in the genomic region associated with successful spring Chinook migration.

Commented [SC71]: Monophyletic has a very specific meaning, and is not directly related to whether or not a life-history trait will arise again if lost. For example, depending on modes of inheritance and allele frequencies, a monophyletic trait could easily be not observed in a population which retains the underlying variation at some frequency.

I understand that the authors are summarizing other work in this section, but I highlight this statement because I think the key is in clarifying the difference between what is being summarized here from Prince et al (2017), and what has been learned from the collection of additional data (Ford et al. 2020, as summarized on lines 5978-5980 of the current document).

Commented [MS72]: Please see my expanded comments on this subject in my written responses to this report. Following the work of Prince et al. (2017) and subsequent work, there is broad scientific agreement that the alleles responsible for spring Chinook migration arose from a single evolutionary event.

Commented [AC73]: Changes made by Shawn Narum

Commented [AC74]: Changes made by Christian Smith intermediate times between the spring and fall. Based on this, the authors concluded that gene expression at *GREB1L* could not be recessive[3], and that heterozygotes might have lower fitness than either spring or fall homozygotes. If this is true, and heterozygotes experience strong selection, the authors conclude that the spring allele could easily be lost.

Thompson et al. (2019) further examined the genetic distribution of the spring and fall migration associated alleles of the *GREB1L* region in both the Rogue and Klamath rivers. The authors re-sequenced the *GREB1L* region in 64 spring and fall samples using some of the same samples used in Prince et al. (2017). The authors identified new SNPs more closely associated with ecotype than Prince et al. (2017). Using newly developed assays for two of these new SNPs, they genotyped 269 Chinook Salmon collected in early, middle, and late phases of their migration period. The authors found a strong association of return timing phenotype with genotype, with early-returning Chinook Salmon mostly being homozygous for the "spring allele," middle returns mostly heterozygous with both alleles, and late returns mostly homozygous for the "fall allele."

Commented [SN75]: Steelhead inheritance is likely different than in Chinook. There needs to be a section on dominance/recessive inheritance in Chinook salmon (Thompson et al. 2019; Koch and Narum 2020) and the implications.

Thompson et al. (2019) also analyzed nine Chinook Salmon samples from Klamath River archaeological sites using the two new SNPs. Age of the samples ranged from approximately 100 years old to several thousands of years old. Samples were from upper Klamath reaches, above the dams slated for removal in 2022. Both spring- and fall-associated alleles were found in these ancient samples indicating that both ecotypes existed in the Upper Klamath River in historical times.

Thompson et al. (2019) also examined UKTR Chinook Salmon samples from the Shasta and Scott rivers to see whether spring *GREB1L* genetic markers were still present despite the absence of spring runs there. The Shasta River has had only a small and inconsistent UKTR spring Chinook Salmon run since the 1930s. Not surprisingly, the authors only found two individuals in 437 samples labeled Shasta River UKTR fall Chinook Salmon that had spring *GREB1L* markers. The authors also analyzed 425 contemporary UKTR fall Chinook Salmon from the Scott River, again finding only two individuals with the spring *GREB1L* markers. The Scott River has not had an appreciable UKTR spring Chinook Salmon return since the 1970s, so these results are also not surprising. All four fish with the spring allele were heterozygotes. Thompson et al. (2019) did, however, find an appreciable number of the spring *GREB1L* ~~markers~~ alleles in samples from Salmon River Chinook Salmon, correlating with the relatively larger size of its spring returning component. ~~Much of the focus of Thompson et al.'s (2019) discussion focuses on considerations for UKTR spring Chinook Salmon stock selection for recolonizing the upper Klamath River post-dam removal.~~

Commented [MS76]: The take home from this aspect of Thompson et al. (2019) is that spring alleles do not persist in fall Chinook populations once the spring Chinook run has disappeared. The results from the Shasta and Scott rivers provide empirical evidence that the alleles needed for spring Chinook runs will not "reemerge" from the genetic background of fall Chinook.

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[3] If a simple complete dominance relationship was expressed there would only be two return types, early (spring) or late (fall). Intermediate return timing of heterozygotes suggests a more complex type of phenotypic expression.

Analyses of adaptive genetic variation have not been limited to Prince et al. (2017) and Thompson et al. (2019). Anderson et al. (2019) and Anderson and Garza (2019) conducted an extensive DNA sequencing study to further refine the actual genomic region associated with migration timing, thus providing more accurate identification than the markers used by Prince et al. (2017) and Thompson et al. (2019). The authors analyzed approximately 200 Chinook Salmon from both runs at TRH and the Salmon River using a new set of genetic markers (SNPs) that are in tighter correlation with migration timing than those used by Prince et al. (2017).

Anderson et al. (2019) found that a substantial number of individuals analyzed possessed both the spring and fall genetic markers (alleles); i.e., there was a substantial number of heterozygotes carrying both spring and fall alleles. He found that only approximately 60% of Trinity River UKTR spring Chinook Salmon contained only the spring markers. The rest were heterozygous for spring and fall markers and about 5-10% of the samples were homozygous for fall markers. A small percentage of the Trinity River fall Chinook Salmon contained both the spring and fall markers, but most contained only the fall marker. The pattern was somewhat different in the Salmon River, where the UKTR spring Chinook Salmon were predominantly homozygous for the spring allele, yet some individuals contained both markers and a small percentage of Salmon River UKTR spring Chinook Salmon were homozygous for fall markers. The UKTR fall Chinook Salmon pattern in the Salmon River was different. Slightly more than half of the Salmon River UKTR fall Chinook Salmon sampled contained only the fall markers while the rest either contained both markers or contained only the spring marker. On the Klamath River, UKTR fall Chinook Salmon from Iron Gate Hatchery (IGH) were exclusively homozygous for the fall allele. Given that the genetic markers used are in tight statistical association with the genomic region affecting migration timing, this pattern shows that the genetic variants linked to one ecotype (e.g., UKTR spring Chinook Salmon) can be carried in individuals showing a different ecotype (e.g., UKTR fall Chinook Salmon) and vice versa.

Commented [SC77]: Singular / plural

Commented [MOU78]: They?

Commented [MS79]: This illustrates that there can be errors in phenotyping Chinook as either "spring Chinook" or "fall Chinook" when they are captured at locations far from the river mouth (e.g., on the spawning grounds or at the hatchery). In coastal Chinook populations, such as in UKT, where marker development has been developed and well validated, the genotype is a more reliable indicator of Chinook migration type. Consequently, the statement that 5-10% of the UKTR spring Chinook had a homozygous fall genotype is incorrect. This result indicates that 5-10% of the UKTR classified as spring Chinook phenotypes based on field calls were wrong and that they were actually fall Chinook. Similarly, Chinook that are heterozygous are not phenotypically spring Chinook. They have intermediate run timing between spring and fall Chinook. These issues of marker development and phenotyping are described in detail in Thompson et al. (2019) and reviewed in Ford et al. (2020).

Commented [MS80]: This is mostly incorrect for the reasons stated in the previous comment. "Fall Chinook" do not carry the alleles necessary for spring migration and vice versa. Hybrids (heterozygotes) have intermediate phenotypes.

Both Prince et al. (2017) and Thompson et al. (2019) found that the *GREB1L* genomic region was highly conserved across multiple other Chinook Salmon ESUs from the Upper Klamath and Trinity rivers and Oregon populations. Anderson et al. (2019) also compared his *GREB1L* genomic data to Central Valley Chinook Salmon populations and likewise found that the spring and fall alleles observed in the UKTR Chinook Salmon were also present in Central Valley spring- and fall-run populations. .

Commented [MOU81]: You may want to add Michelletti (sp?) paper by Narum's group that shows a role for ROCK.

Commented [MS82]: I believe this was covered elsewhere, but this pattern of a conserved haplotype associated with spring Chinook in many diverse populations provides evidence for the monophyletic origins of the alleles necessary for spring Chinook migrations.

In response to the most recent federal ESA petition to list UKTR spring Chinook Salmon, Anderson and Garza (2019) conducted additional analyses expanding on the biology of the *GREB1L* association described in Prince et al. (2017) and other previous studies. The following is a summary of their findings:

1. Whole genome sequencing data reveal a region of the genome near *GREB1L* with variation shared by all spring Chinook Salmon ecotypes surveyed in California, including

UKTR spring Chinook Salmon and Central Valley spring-run Chinook Salmon, and winter-run Chinook Salmon.

2. Genotyping of the region of strongest genetic association (RoSA) markers on Chinook Salmon from the Yurok tribal fishery shows that RoSA genotype accurately predicts the freshwater entry time of Chinook Salmon in the Klamath River, but does not predict the level of reproductive maturity or fat content after accounting for sampling date.
3. There is a remarkable degree of spatial and temporal overlap of spring (EE[4]) genotypes, with fall (LL) and heterozygous (EL) genotypes of Chinook Salmon on the spawning grounds of the Salmon River.
4. The proportion of different genotypes from carcasses in the Salmon River in any given year is consistent with limited assortative mating[5] between spring and fall ecotypes.
5. Based on limited assortative mating of ecotypes, heterozygotes are predicted to produce a sizable fraction of the spring and fall Chinook Salmon returns each year.
6. It is unlikely that the substantial genetic exchange between UKTR spring and fall Chinook Salmon in the Klamath basin is solely a consequence of increased introgression due to anthropogenic changes in the last 100 years.
7. The spring migration timing allele is still quite abundant within the Klamath basin.

Results of a recent workshop exploring the state of the science, conservation implications, and future research needs regarding the simple genomic association with run timing in Chinook Salmon and steelhead is documented in Ford et al. (2020). A summary of the areas of agreement and uncertainty among the workshop participants is presented in Appendix D.

Although all of the findings and discussion in Ford et al. (2020) are important, the following selected conclusions are excerpted here because they are especially relevant to this status review:

1. A single region in the genome has a strong statistical association with adult run timing.
2. The causal variant(s) for adult run timing remain to be identified.
3. Heterozygotes are likely an important mechanism for the spread and maintenance of the early migration alleles over long time scales.
4. The early and late allelic variants that have been well characterized evolved long ago in each species' evolutionary history. The allelic variants for early migration

Commented [MS83]: The winter Chinook similarity with spring Chinook is interesting. It is true that the two forms have shared variation, but my understanding is that there is additional variation in this region that reliably distinguishes between these Chinook runs.

Commented [MS84]: Two points: 1) Isn't freshwater entry timing completely confounded with sampling date? So how could this analysis approach produce meaningful comparisons of maturity in spring and fall Chinook?

Commented [MS85]: Could this be the result of modification to Bloomer Falls on the Salmon River that allowed for increased upstream access by fall Chinook?

See:
Olson AD, Dix OJ. (1991) Lower Salmon River Sub-basin Fish Habitat Condition and Utilization Assessment 1990/1991 Final Report. USDA – Forest Service, Klamath National Forest.

Commented [MS86]: Is this completely accurate? Ford et al. (2020) summarized areas of agreement on this subject: "Participants agreed that interbreeding between runs likely occurred historically (i.e., pre-European immigration) in many or most locations, but estimating precise natural/historical levels of interbreeding is challenging. For example, an analysis of recombination patterns in the Salmon River (Klamath) rejected the hypothesis that zero interbreeding occurred between spring and fall runs prior to 200 years ago, but did not distinguish between levels of historical interbreeding (e.g., 1% vs 25%; Anderson presentation)" (p. 35). If the analysis of Anderson and Garza could not estimate historical levels of interbreeding between spring and fall Chinook (other than it not being zero), then how can they conclude that substantial genetic exchange is not due solely to anthropogenic change? For example, if historical levels of interbreeding were 1% and they are now, say, 25% due to anthropogenic change, wouldn't that represent a substantial increase due to human causes? This statement does not appear to be fully supported by their analyses.

Commented [MS87]: Relative to what benchmark? Does this include Trinity hatchery spring Chinook?

Commented [SC88]: Plural / singular

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[4] In this notation, E=the spring ("early") allele, L= the fall ("late") allele. Possible genotypes and phenotypes are EE, homozygous spring; LL, homozygous fall; EL, heterozygous intermediate.

[5] A mating pattern in which individuals with similar phenotypes mate with one another more frequently than expected by chance.

have not arisen independently via new mutations from the genomic background of late migration individuals in each watershed.

5. ~~Conservation units should continue to be defined by patterns of genetic diversity across the genome, rather than by variation in small genomic regions correlated with specific traits of interest, such as run timing~~. Using patterns of genetic variation throughout the genome remains important for identifying conservation units, rather than identifying units based solely on small genomic regions associated with specific traits.
6. Spring Chinook salmon and summer steelhead occupy a specialized ecological niche—upstream areas accessible primarily during spring flow events—that has made them particularly vulnerable to extirpation or decline due to habitat degradation.
7. The evaluation of risk to early returning groups (e.g., spring-returning Chinook salmon, summer steelhead) needs to consider what we now know about the genetic basis of adult return time.
8. The finding that the "early run" trait has a simple genetic basis implies that the "early run" phenotype is at greater risk than if the trait resulted from many genes because loss of the "early" allele(s) equates to loss of the phenotype.

Commented [MS89]: I think you should include the report's verbatim conclusion here because it is different in subtle but important ways. The conclusion is that genetic variation throughout the genome remains an important part of conservation unit designation and that conservation units shouldn't be defined solely based on small genomic regions. It does not say that conservation units should be defined by patterns of genetic diversity across the genome, *rather* than by variation in small genomic regions. In other words, both types of information can be useful for considering conservation units. This is consistent with the recommendations of Waples (1991) who stated: "*The best strategy is to use all available lines of evidence for or against reproductive isolation, recognizing the limitations of each and taking advantage of the often complementary nature of the different types of information*" (p. 11).

2.6.4 Patterns of Genetic Structure

Commented [MS90]: The contrast in contemporary genetic structure of Chinook in the Klamath and the Central Valley is potentially interesting. Please see my comments provided in my review summary.

The pattern of genetic diversity observed in UKTR Chinook Salmon is best understood in context with other California Chinook Salmon populations. The pattern of genetic structure within the UKTR Chinook Salmon ESU is in stark contrast to that underlying differences between Chinook Salmon migration timing in the Central Valley. Both the Central Valley winter-run and spring-run are listed as separate ESUs under both ESA and CESA. Genetic analyses of Central Valley Chinook Salmon populations show clear genetic differentiation between winter-, spring-, and fall/late fall-run Chinook Salmon (Meek et al. 2016; Clemento et al. 2014; Garza et al. 2007; Figure 2.10). Within the Central Valley, this pattern is consistent with each migration timing life-history strategy having arisen only once (i.e., it is monophyletic) and all three runs represent separate, unique evolutionary lineages. Thus, if one of those ecotypes is lost, it will most likely not reemerge from an existing stock. The heavy introgression between spring- and fall- runs in the Feather and Yuba rivers as a result of previous hatchery practices at Feather River Hatchery, along with dam construction and water management in the Feather, Yuba, and Sacramento rivers, complicates this pattern. However, the introgressed stocks in the Feather River are exceptions caused by anthropogenic actions that resulted in interbreeding and repeated backcrossing between spring- and fall-run Chinook Salmon in that river system. As a result of the pattern of genetic structure and reproductive isolation in Central Valley Chinook Salmon populations, the winter-, spring- and fall/late-fall are considered separate ESUs. Sacramento winter-run Chinook Salmon are listed as "endangered" and Central Valley spring-run Chinook Salmon were listed as "threatened" first under ESA and subsequently under CESA. Central Valley fall/late fall-run Chinook Salmon are not listed under either act.

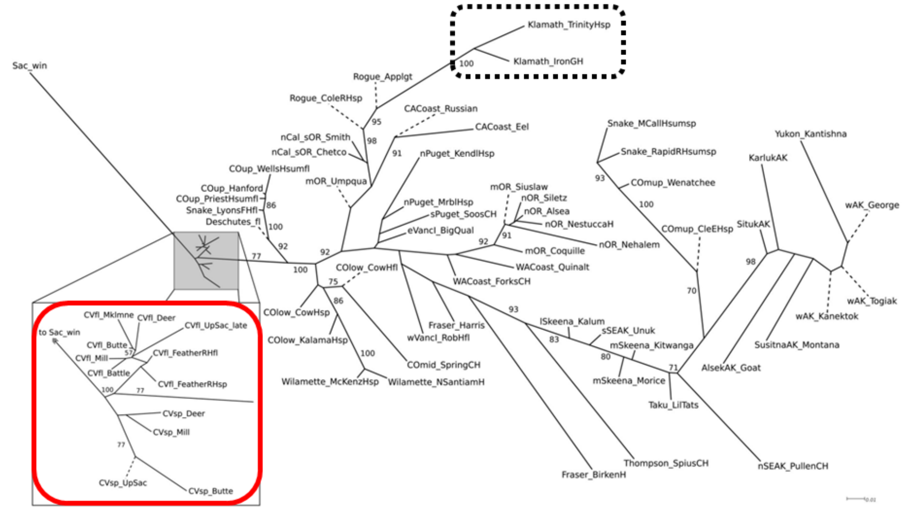

Figure 1

Unrooted neighbor-joining tree constructed with chord distances of 67 populations of Chinook Salmon (*Oncorhynchus tshawytscha*) from California to Alaska in the genetic stock identification baseline (see Table 1 for population details). Dashed lines indicate the position of populations that fall at tree junctions or have very short branch lengths. The Sinona Creek population does not appear in the tree because of the failure of one locus; however, analysis with a truncated set of loci (not shown) revealed clustering with the other Alaska populations. The single collection of Coho Salmon (*Oncorhynchus kisutch*) from California also were omitted.

Figure 2.10. Figure 1 from Clemento et al. (2014) with modification to show genetic relationships of Central Valley Chinook ESUs and Klamath-Trinity Chinook. Central Valley Chinook ESUs in red solid box; Klamath-Trinity samples in black broken dash box.

On a broader geographic scale, Moran et al. (2013) provide a comprehensive discussion of the complexities of evolutionary lineage, biogeographic differences, and the complex colonization history of Chinook Salmon throughout their range. Those authors examined 19,679 samples from 280 collections using 13 microsatellite loci. They found that the level of genetic divergence between life history types is widely variable. While the interior Columbia River populations showed significant divergence between life-history types, most other populations did not. The authors did include both spring and fall Chinook Salmon from the Trinity River but did not comment on the level of genetic divergence between spring and fall Chinook Salmon ecotypes. In summary, the authors emphasized that evolutionary lineage should be described as the life-history strategy coupled with location and further recommended that recognition of group-specific life-history diversity is important for conservation because restoration and recovery efforts typically target life-history types as opposed to lineages.

The mere existence of different life-history strategies does not necessarily mean that they are genetically unique and reproductively isolated. As Moran et al. (2013) discuss, the correlation between life-history strategies and evolutionary lineage is largely situationally dependent. For example, California Central Valley stocks have very distinct irreplaceable Chinook Salmon lineages. Conversely, UKTR Chinook Salmon represent several lineages that are specific to location, not run-timing. Genetically, UKTR spring Chinook Salmon share the same form of *GREB1L* that is also found in multiple other spring Chinook Salmon populations within and outside the Klamath basin, and some individuals are heterozygous for both the spring and fall alleles (Anderson and Garza 2019). Given that there is clear genetic separation of different migration timing lineages for both neutral (e.g., microsatellite and SNP) and adaptive markers among Central Valley populations but not in the UKTR Chinook Salmon ESU, it would not be appropriate to automatically apply the same ESU designations based on run-timing in the Klamath basin because the pattern of genetic differentiation is markedly different.

Addressing Prince et al. (2017) and Thompson et al. (2019) specifically, the Department recommends an abundance of caution regarding the use of single putative adaptive genetic markers such as those from the *GREB1L* region when delineating conservation units pursuant to CESA listing decisions. First, the study reported in Prince et al. (2017) was designed to study the genetic basis of migration timing not reproductive isolation. Samples in that study were from opposite ends of the distribution for fall and spring spawning migrants. Modeling from Thompson et al. (2018) suggested overlap in spawning of fall homozygotes, fall-spring heterozygotes, and spring homozygotes. Second, Waples and Lindley (2018) directly address the appropriate use of genomic data, primarily in response to the Prince et al. (2017) paper. They note that at times the patterns of genetic structure will be similar for both neutral (e.g., microsatellite DNA) and adaptive (e.g., *GREB1L*) markers, while at other times, the patterns may be quite different (e.g., as in Prince et al. 2017). This is problematic because if the goal of conservation is to protect biodiversity, then the geographic delineation of conservation units may be drastically different between existing ESUs constructed largely from traditional DNA typing methods and new boundaries reflecting the adaptive genetic markers for a hypothetical petitioner’s life-history trait of choice. Current practice is to protect overall genetic diversity so that a species or ESU will have the greatest possible resilience, allowing it to adapt to future environmental conditions, rather than focus on variation at one specific gene.

Waples and Lindley (2018) go on to explain why a shift to defining conservation units based on adaptive markers alone may be problematic. First, the scientific community does not yet know exactly how this putative marker is distributed in time and space. Prince et al. (2017), Thompson et al. (2019) Anderson and Garza (2019), and Anderson et al. (2019) indicate that the same spring and fall alleles observed in UKTR Chinook Salmon are also present in other Chinook Salmon populations that they surveyed. Second, it is not clear whether the genes identified are actually the ones responsible for migration timing differences. This is still an unresolved but active area of research. Third, details of the pattern of dominance are only recently being explored. Specifically, it is important to know whether spring alleles can persist in fall Chinook Salmon as more recent studies suggest (e.g., Anderson and Garza 2019). Despite having had no appreciable spring-migrating returns in several decades, Thompson et al. (2019) found a handful of fall Chinook Salmon in the Shasta and Scott rivers with the spring *GREB1L* allele. Anderson et al. (2019) found that both UKTR spring and fall Chinook Salmon can indeed contain both the late-returning (fall) and early-returning (spring) forms of *GREB1L* in the same individual. Waples and Lindley (2018) additionally ask why the pattern of genetic diversity associated with this single gene is so different from thousands of other genetic markers? What if additional research finds that *GREB1L* is not the causative early migration factor, but another nearby gene region is?

Commented [SN91]: There is strong evidence that the adjacent ROCK1 gene plays a role in migration timing, however it is closely linked with GREB1L in the same region of Chr28 (Narum et al. 2018; Koch and Narum 2020). This region on Chr28 containing these two genes is clearly a large effect locus associated with adult migration in Chinook salmon populations across the range, however it is highly unlikely that another region of the genome is causative

Waples and Lindley (2018) pose the question of picking a particular trait or gene of interest when defining conservation units. While they agree that migration timing is important and is used in many management contexts, it would be an unprecedented approach to delineation of conservation units. They advocate that both neutral and adaptive genetic information need to be considered in concert with one another. With respect to migration timing specifically, they ask the question "If an early-migrating population is lost, under what circumstances, and over what time period, might it be restored?" Thus, if UKTR spring Chinook Salmon became completely extirpated, could they be restored from existing genetic variation in nearby locations (e.g., Upper Trinity River UKTR spring Chinook Salmon or heterozygous UKTR fall Chinook Salmon). The detection of UKTR fall Chinook Salmon that are heterozygous for the spring and fall alleles of the *GREB1L* gene region suggests this is possible[6]. Importantly, if UKTR spring Chinook Salmon were listed separately from UKTR fall Chinook Salmon, fall-migrating heterozygotes, not protected under CESA, would be expected to produce both protected UKTR spring Chinook Salmon and unprotected UKTR fall Chinook Salmon offspring in the same family. This has potential to present a serious conservation and management dilemma.

2.6.5 Conclusions regarding Genetics and Genomics

There have been substantial genetic analyses conducted on UKTR Chinook Salmon using a variety of methods. Collectively these studies show that geographic location within the Klamath basin largely defines reproductively isolated units, as opposed to run-timing. Spring and fall Chinook Salmon in the Klamath basin that are found in the same stream are more similar to one another than to either spring or fall Chinook Salmon in more distant streams. This result strongly validates the "isolation by distance" model for UKTR spring and fall Chinook Salmon in the basin. Population genetic and overlapping spawning distribution data indicate that UKTR spring and fall Chinook Salmon are best described as ecotypes that together comprise local breeding units across the Klamath-Trinity watershed.

The most recent genetic analyses using genomic methods focus on a key region of the Chinook Salmon genome that has a very strong association with run timing. One form of this region is

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[6] The differential abundance of UKTR spring Chinook Salmon and their current concentration in the Upper Trinity River suggest that natural recovery of UKTR spring Chinook Salmon in the Klamath River, even after dam removal, could take a long time.

associated with the UKTR spring ecotype and the other with the UKTR fall ecotype. It has also been demonstrated that an individual UKTR Chinook Salmon can have one copy of the spring allele and one copy of the fall allele and that heterozygotes have intermediate run-timing. Through inheritance from one generation to the next, this means that heterozygotes can produce offspring that display either run-timing phenotype, or potentially produce a single family containing some offspring that return in the spring while other full siblings return in the fall. The spring and fall forms of this gene region are not unique to UKTR Chinook Salmon but appear to be widespread across multiple Chinook Salmon ESUs. Although UKTR Chinook Salmon show a monophyletic pattern at a single gene region, whole genome data do not. Available genetic data, both genome-wide and within the *GREB1L* region suggest historic and current reproductive exchange between UKTR spring and fall Chinook Salmon in the Klamath basin. Given that UKTR spring Chinook Salmon are not a unique genetic entity, but can and do interbreed with UKTR fall Chinook Salmon, it is reasonable to conclude (as NMFS has done) that the spring-returning phenotype could reemerge from existing standing genetic variation should it become locally extirpated. The Department agrees with previous federal status reviews (Myers et al. 1998, Williams et al. 2013) that UKTR spring Chinook Salmon do not meet the commonly used genetic criteria to be considered separate ESU.

Commented [SN92]: While early alleles could be introduced from nearby populations to restore spring run fish, it is highly unlikely that the early alleles from standing genetic variation would be adequate to restore spring run fish if lost. Further comment is needed to address this point.

The strong genomic association of *GREB1L* and associated regions with adult migration timing (e.g., Prince et al. 2017) is an important result that sheds light on the genetic underpinnings of early run timing in Chinook Salmon and other salmonids. However, the Department finds that this genomic association is only one part of the total evolutionary heritage of UKTR spring Chinook Salmon and, by itself, is not sufficient or appropriate differentiation to create a new UKTR spring Chinook Salmon ESU.

3. Range and Distribution

3.1 Range

Chinook Salmon spawning populations range across the North Pacific Rim from California to Alaska in North America and into Asia from northern Japan to the Palyavaam River in Siberia (Augerot and Foley 2005; Figure 3.1). Spawning populations in North America range from Kotzebue Sound in Alaska to the southernmost populations in California's Central Valley. Except in some drainages of Kamchatka, Chinook Salmon distribution in Asia is sparse and the species is best represented in the Pacific Northwest of North America. The inland range of the species has been truncated in many places by dam construction and habitat alteration.

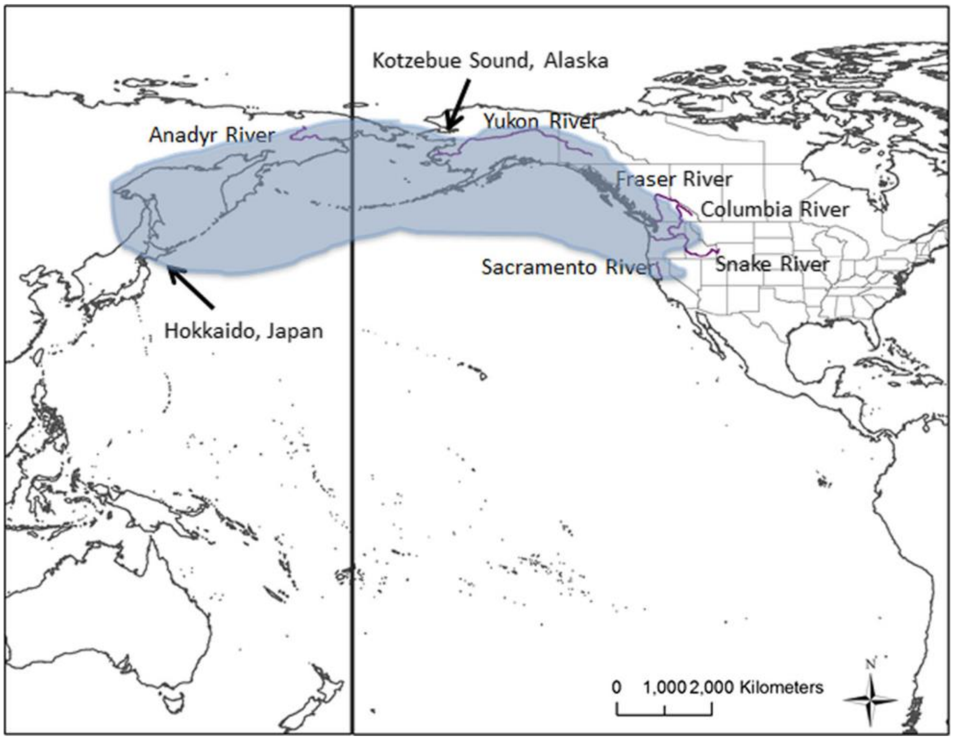

Figure 3.1. Native range of Chinook Salmon. The shaded region represents approximate current freshwater and marine distribution. From: Bourret et al. 2016, citing Healey 1991 and Augerot 2005.

Chinook Salmon have also been translocated to many non-native areas where they are either farmed or exist as a naturalized species. Notable translocations include the Great Lakes, Patagonia, and New Zealand, where naturalized populations have been established. A list of non-indigenous Chinook Salmon occurrences in the U.S. can be found at: https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=920.

The UKTR Chinook Salmon ESU contains both spring and fall ecotypes. The fall ecotype, as in historical times, is widely distributed across the Klamath-Trinity basin (below dams). Both ecotypes have experienced historical range truncations due to dam construction in both the Klamath and Trinity rivers.

The UKTR spring Chinook Salmon ecotype historically ranged throughout the Klamath and Trinity river basins, including upstream of current impassable dams. Holding and spawning occurred in larger tributaries (e.g., Salmon River) and, depending on flows, in some smaller tributaries. UKTR spring Chinook were historically abundant and widely distributed in major Klamath basin tributaries, e.g., Salmon River, Scott River, Shasta River, South Fork Trinity River, and North Fork Trinity River (Moffett and Smith 1950).

The current range of the UKTR Chinook Salmon ESU is restricted by dams to the lower portions of the Klamath and Trinity Rivers. Only the Upper Trinity River, Salmon River, and the South Fork Trinity River currently contain spawning assemblages of the UKTR spring Chinook Salmon ecotype. In the Salmon River, approximately 285 rkm (177 RM) are accessible to UKTR spring Chinook Salmon (West 1991). However, much of that is underutilized or unsuitable for spawning. In the Salmon River, most spawning occurs in the South Fork. UKTR spring Chinook Salmon redds have been found in smaller Salmon River tributaries such as Nordheimer, Knownothing, and Methodist creeks. Small numbers of UKTR spring Chinook Salmon have been observed in Elk, Indian, Clear and Wooley creeks.

Trinity River Hatchery (TRH) also produces hatchery UKTR spring Chinook Salmon. Many of the fish returning to the Trinity River are of hatchery origin. However, although a large proportion of hatchery-origin spawning fish return to TRH, a substantial portion of annual returns to natural spawning areas in all years are of natural-origin (see also *Section 6.7 Factors Affecting the Ability to Survive and Reproduce, Hatcheries*).

3.2 Historical and Current Distribution

The Klamath River basin is California’s second largest river system, draining a watershed of approximately 40,404 square km (15,600 square miles). The watershed is commonly divided into the Lower Klamath River below Klamath Lake, the Upper Klamath River above Klamath Lake, and the Trinity River basins. Diverse climate and landscape are observed across the basin. Unique among Pacific drainages, the Klamath basin starts in lower gradient marshes and inland desert environments, transitioning to higher gradient slopes below Klamath Lake (Stanford et al. 2011; Thorsteinson et al. 2011).

Anadromous fish have been blocked from the Oregon reaches of the upper Klamath basin since 1918 when Copco No.1 Dam was constructed (Figure 3.2; USDI et al. 2012). Currently, anadromous fish have access to about 306 km (190 miles) of the Klamath River (from Iron Gate Dam, near the Oregon border in Siskiyou County, to the Pacific Ocean at Requa in Del Norte County). Approximately 1,296 km (805 miles) of suitable Chinook Salmon habitat was estimated to have been lost due to the construction of Iron Gate Dam (CDFG 1965). This estimate was updated by Hardy and Addley (2006) to approximately 1,128 km (701 miles) of spawning habitat above the dam.

Historically, UKTR spring Chinook Salmon may have been as or more abundant than UKTR fall Chinook Salmon in the Klamath basin (Moyle 2002). It is likely that on the order of hundreds of thousands of fish occupied tributaries throughout the basin including the Sprague and Williamson rivers in Oregon (Moyle 2002). Tribal oral histories, historic photographs, early scientific reports, and first-hand accounts of the earliest non-native explorers of the Klamath basin all describe prolific runs of both UKTR spring and fall Chinook Salmon migrating into the headwaters of the Klamath River upstream of Upper Klamath Lake (Hamilton et al. 2005).

The Trinity River is the largest tributary to the Klamath River and drains approximately 3,546 square km (1,369 square miles) of watershed. The headwater streams originate in the Trinity Alps and Trinity Mountains in eastern Trinity County. The river flows 277 km (172 miles) south and west through Trinity County, then north through Humboldt County and the Hoopa Valley and Yurok Indian reservations until it joins the Klamath River at Weitchpec, about 64 rkm (river kilometers; 40 river miles (RM)) from the Pacific Ocean. Anadromous fish passage is blocked by Lewiston Dam approximately 177 rkm (110 RM) upstream from the mouth of the Trinity River.

Historical UKTR spring Chinook Salmon spawning in the Trinity River occurred in the East Fork, Stuart Fork, Coffee Creek, and the mainstem Upper Trinity River (Campbell and Moyle 1991). Approximately 56 km (34.8 miles) of prime spawning and rearing habitat for UKTR Chinook Salmon was blocked by construction of Trinity Dam in 1962 and Lewiston Dam in 1963. Small numbers of UKTR spring Chinook Salmon are currently observed in Hayfork and Canyon creeks, as well as in the North Fork Trinity, South Fork Trinity, and New rivers. Of these, only the South Fork Trinity River is documented to be composed of natural-origin fish. UKTR spring Chinook Salmon spawn in the New River and North Fork Trinity River; however, it is not known whether these are separate populations (W. Sinnen, CDFW, personal communication, 2020). In the South Fork Trinity River, LaFaunce (1967) found that UKTR spring Chinook Salmon spawned from about 3 km (1.9 mi) upstream of Hyampom. The authors also noted spawning in Hayfork Creek for approximately 11 km (6.8 miles). The highest density of redds in the South Fork Trinity River was between rkm 60.7 (37.7 miles) and 111.8 (69.5 miles) in 1964 (LaFaunce 1967) and 1995 (Dean 1996).

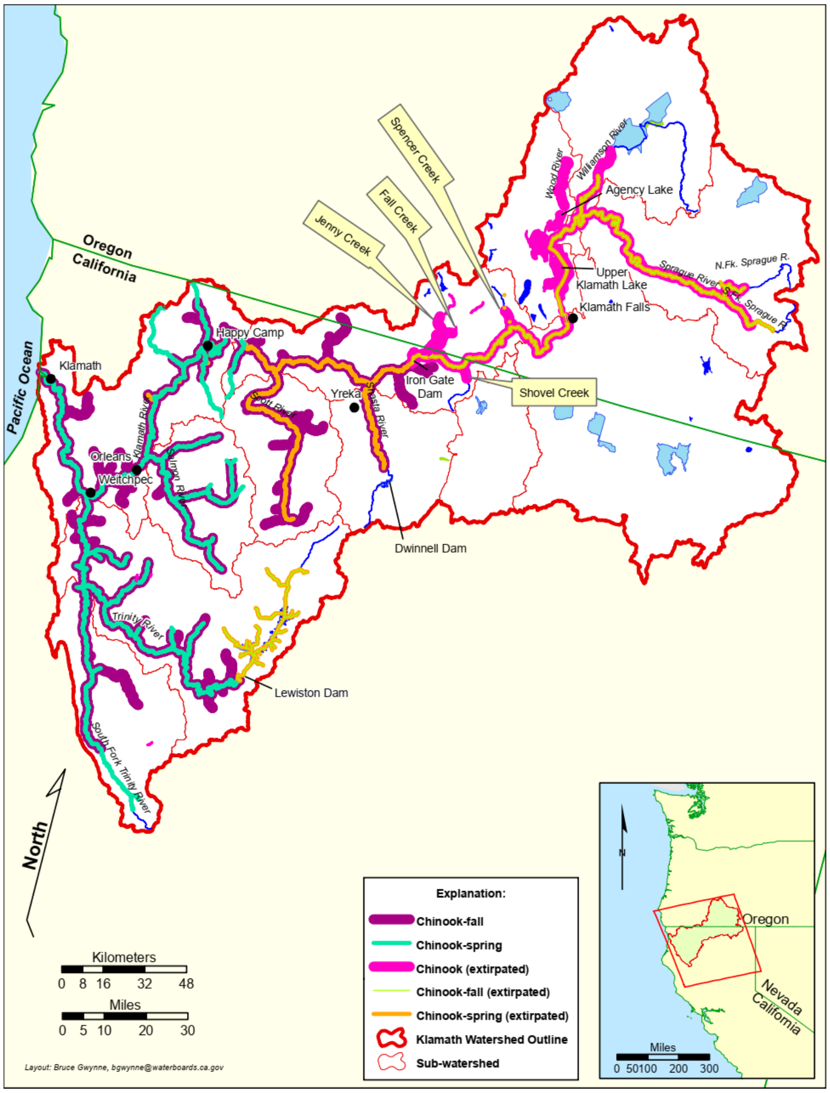

Figure 3.2. Current and historical (extirpated) distribution of UKTR Chinook Salmon in the Klamath and Trinity Rivers (Original map from Carter and Kirk (2008). Streams shown as “extirpated” do not differentiate between UKTR spring and fall Chinook Salmon. Data

sources: Hamilton et al. 2005, p. 12; Moffett and Smith 1950, pp. 23 and 27; Moyle 2002, p. 259; USFS 1996; USFS 2006.

UKTR spring Chinook Salmon also historically spawned in the tributaries of the Upper Klamath River basin (Moyle 2002; Hamilton et al. 2005; Hamilton et al. 2016) with large numbers spawning upstream of Klamath Lake in the Williamson, Sprague, and Wood rivers (Snyder 1931). The earliest reference to Chinook Salmon in the Upper Klamath River that the Department is aware of (referenced in Lane and Lane Associates 1981) is Fremont's May 1846 observation of large numbers of salmon at the outlet of Klamath Lake. Based on migration timing, these were likely UKTR spring Chinook Salmon.

Hamilton et al. (2005) conducted a study of the historical distribution of anadromous fish above Iron Gate Dam on the Klamath River. They found substantial evidence that, prior to dam construction, large numbers of both spring and fall Chinook Salmon migrated as far as the Sprague River (OR). The authors found numerous accounts of Chinook Salmon in tributaries of Upper Klamath Lake (e.g., Williamson and Sprague Rivers). Hamilton et al. (2016) note that it is possible that fall Chinook (migrating August-October/November) may have only reached Upper Klamath Lake and further tributaries in wetter years.

Spring-migrating (April-August) Chinook, because of their earlier run-timing, and possibly their smaller size, may have more consistently accessed those upper basin streams. This suggests a possible mechanism for that may have resulted in more substantial historical reproductive isolation of UKTR spring and fall Chinook Salmon runs.

Large runs of UKTR spring Chinook Salmon are also thought to have historically returned to the Shasta, Scott, and Salmon rivers (Moyle et al. 1995). Wales (1951) reported that only 8% of the historic salmon returns to the Shasta sub-basin were UKTR fall Chinook Salmon. Dwinell Dam, built in 1926 on the Shasta River, blocked approximately 22% of the spawning habitat in that system (NRC 2004).

Myers et al. (1998) also speculated that the spring ecotype may once have been the dominant Chinook Salmon run in the Klamath River basin. Historically, large numbers of spring Chinook Salmon migrated through the Mid-Klamath River to the Upper Klamath River basin prior to dam construction. Upstream distribution was truncated by dam construction. Blockage by dams also restricted UKTR Chinook Salmon to downstream reaches, exposing then to warm Klamath River main stem water temperatures. This likely limits the quality and quantity of the ESU as a whole but may disproportionately affect critical UKTR spring Chinook Salmon adult holding locations.

Currently, spawning aggregations of UKTR spring Chinook Salmon are mainly found in three places in the Klamath-Trinity: Upper Trinity River, South Fork (SF) Trinity River, and Salmon River. Small numbers of UKTR spring Chinook Salmon are found in a few other places with intermittent occupancy. These include the Trinity River tributaries Hayfork Creek, North Fork Trinity River, and New River. Miscellaneous monitoring of UKTR spring Chinook Salmon in

Klamath Tributaries can include tributary creeks in both the USFS Orleans/Ukonom and the US Forest Service (USFS) Happy Camp Ranger Districts. Reported numbers of UKTR spring Chinook Salmon in both drainages are incidental to summer steelhead surveys conducted by USFS (Dan Troxel, CDFW, 10/29/2019, personal communication). Soto et al. (2008) reported that spring Chinook Salmon can also be found in Mid-Klamath tributaries with cold, deep holding pools such as Dillon, Clear, Elk, Indian and Thompson creeks; however, these occurrences are usually at very small numbers (10 or less).

UKTR fall Chinook Salmon spawn in all reaches of the Salmon River mainstem. Adult UKTR spring Chinook Salmon rarely spawn in the lower Salmon River mainstem; however, some adults have been observed on redds within the upper mainstem above Crapo Creek (RM 15.4) when conditions are good.

- **Wooley Creek (RM 5.0):** UKTR fall and spring Chinook Salmon are known to occupy suitable habitat up to Big Meadows Creek (RM 15.8) within the mainstem of Wooley Creek. However, most annual spawning and rearing occurs below a bedrock chute located at RM 9.6.
- **Nordheimer Creek (RM 14.9):** Adult fall Chinook Salmon are found along 2.6 miles of Nordheimer Creek. However, most spawning and rearing occurs within the mainstem below the fish ladder at RM 1.7. In addition, UKTR spring Chinook Salmon are commonly observed holding within this lower reach.

The South Fork of the Salmon River holds the majority of both UKTR fall and spring Chinook Salmon in the Salmon River. Spring Chinook Salmon are known to occupy habitat that extends above the Little South Fork (RM 28). When stream flows and river conditions are favorable, fall-run Chinook are found as far as Cecilville (RM 22); however, most fall Chinook salmon are spawn below the Matthews Creek boulder sieve around RM 10.3.

- **Knownothing Creek (RM 2.4):** UKTR fall Chinook salmon spawn within 2.5 miles of the Knownothing Creek mainstem, as well as the lower East Fork for approximately 0.6 RM and the West Fork for approximately 0.3 RM. There are no records of UKTR spring Chinook Salmon spawning within this watershed.
- **Methodist Creek (RM 6.4):** UKTR fall Chinook Salmon spawning occurs along the mainstem about 0.9 miles but may extend farther during high flows to river mile 2.4. There are no records of UKTR spring Chinook Salmon holding or spawning in this tributary.
- **Plummer Creek (RM 13.5):** Both UKTR fall and spring Chinook Salmon are known to occupy suitable habitat within the lower mile of the Plummer Creek mainstem.
- **East Fork Salmon River (RM 20.5):** UKTR spring Chinook Salmon are found along the mainstem up to Shadow Creek (RM 4.8). There are no records of fall Chinook Salmon spawning in the East Fork Salmon River.

UKTR spring Chinook Salmon occupy suitable habitat in the North Fork Salmon River as far as Big Creek (RM 26.5). Under high flow conditions, fall Chinook Salmon have been observed spawning as far upstream as Sawyers Bar (RM 14.8). However, both fall and spring Chinook Salmon primarily spawn within the mainstem of the North Fork up to the Little North Fork (RM 11).

- **Little North Fork (RM 11):** UKTR fall and spring Chinook Salmon are known to spawn within the mainstem to Specimen Creek (RM 2.3).

In the Salmon River, spawning starts in mid-September, whereas in the South Fork Trinity River spawning begins in late-September with a peak in mid-October (LaFaunch 1967). UKTR spring Chinook Salmon spawning in the Trinity River begins 4-6 weeks earlier than for UKTR fall Chinook Salmon (Moffett and Smith 1950). Historical overlap in UKTR spring and fall Chinook Salmon spawning areas may have been less than is currently observed. Current spatial separation of UKTR spring and fall Chinook Salmon spawning in the Klamath-Trinity basin is at approximately 518 m elevation. In the South Fork Trinity River, most UKTR spring Chinook Salmon spawning occurs upstream of Hitchcock Creek, above Hyampom Valley. Most UKTR fall Chinook Salmon spawning is below Hitchcock Creek (LaFaunce 1967; Dean 1996). Spawning area overlap was reported to occur in October in the East and North Forks Trinity River, creating conditions suitable for interbreeding of UKTR spring and fall Chinook Salmon (Moffett and Smith 1950). UKTR spring and fall Chinook Salmon spawn timing in the Salmon River overlaps (as illustrated above), but redds above Matthews Creek are mostly from the spring ecotype.

All UKTR spring Chinook Salmon runs in the Upper Klamath Basin are thought to have been in substantial decline by the early 1900s and were extirpated in the Upper Klamath River by the completion of Copco No. 1 Dam in 1917 (Snyder 1931). Neither spring nor fall Chinook Salmon currently exist above the dams. However, dam removal is anticipated to begin 2022 if permits are received on schedule and is likely to result in migration of UKTR fall Chinook Salmon to the Upper Klamath River. Removal of barriers to migration will also provide conditions that allow natural expansion of UKTR spring Chinook Salmon to historical reaches of the Klamath River; however, small numbers and limited current distribution in the Klamath River may extend the time necessary for natural UKTR spring Chinook Salmon expansion.

In contrast to UKTR spring Chinook Salmon, UKTR fall Chinook Salmon are broadly distributed in the Klamath-Trinity Watershed. They are currently found throughout the Klamath-Trinity basin below dams that form the limit of anadromy. UKTR spring Chinook Salmon spawning areas overlap substantially with those for UKTR fall Chinook Salmon (Figure 3.2).

3.3 Ocean Distribution

The Department evaluated ocean distribution of TRH hatchery-origin UKTR spring Chinook Salmon using coded wire tag (CWT) data available through the Regional Mark Processing Center (www.rmis.org). Individual CWT codes were identified as UKTR spring Chinook Salmon using the species code (Chinook), run type code (1) and hatchery location code (TRH). Recoveries expanded for hatchery production (the proportion of total released fish that were CWT tagged and adipose fin-clipped) and sample rate (the proportion of the fishery by time and area that was observed) were summarized by ocean salmon fishery management area as described in the Pacific Fishery Management Council's (PFMC) Salmon Fishery Management Plan (FMP; PFMC 2016).

Coded-wire tag data recovered from commercial and recreational ocean salmon fisheries since brood year 1976 show that the ocean distribution of Trinity River Hatchery-origin UKTR spring Chinook Salmon ranged from British Columbia, Canada, to San Luis Obispo Bay, California (N = 6,281). Recoveries north of Cape Falcon, Oregon, were uncommon (N = 83 recoveries, 1.3% of all recoveries) and occurred outside the boundaries of available fisheries management. Recoveries south of Point Sur, California, were also uncommon (N = 7), though within reach of potential management actions.

4. Status and trend

4.1 Structure and Function of Viable Salmonid Populations

Salmon have strong fidelity to breeding in the stream of their origin. This provides the potential for substantial reproductive isolation of local breeding populations and adaptation to local environmental conditions. Isolated populations are subject to different levels of genetic drift and natural selection regimes that tend over time to result in differences between them. In addition, populations arising through colonization or artificial propagation, and populations that have experienced recent drastic reductions in abundance, are often genetically different from the population from which they were derived. Salmon also naturally exhibit variable amounts of exchange among populations that connect them genetically and make them more alike. Even small amounts of gene flow between stocks (e.g., due to straying or interbreeding of ecotypes) can prevent complete separation of populations unless there is strong differential selection to maintain that separation (Nei 1987). The amount of exchange observed among populations is influenced by natural and/or anthropogenic environmental factors like stream blockages (e.g., sandbars at the mouths of rivers or road crossings) and straying. Because of these factors, salmon populations tend to be largely, but often not completely, isolated.

Levins (1969) proposed the concept of the metapopulation to describe a “population of populations.” Metapopulations are comprised of subpopulations of local breeding groups, with limited exchange among the subpopulations so that they exhibit both some level of isolation and connectivity. Similarly, larger assemblages (e.g., all breeding populations in a watershed) can themselves form a metapopulation due to the connection between them afforded by natural straying. Fragmentation of this structure can affect the ability of populations to respond to natural environmental variation and catastrophic events. Differential productivity among habitat patches can lead to a “source-sink” relationship in which some highly productive habitats support self-sustaining subpopulations, whereas other less productive habitats persist only through migrants from nearby places.

Using the best scientific information available, this review considers the UKTR spring Chinook Salmon to be an ecotype of the combined UKTR (spring plus fall) Chinook Salmon ESU. Spring and fall Chinook Salmon ecotypes arrive at the spawning grounds at different times but have overlapping spawning times and locations (see *Section 3 Range and Distribution*). Because of this, the two ecotypes are not substantially reproductively isolated (Myers et al. 1998; Williams et al. 2013; Kinziger et al. 2008a, 2008b, 2013), and UKTR Chinook Salmon populations (i.e., together comprising the UKTR Chinook Salmon ESU) may contain both spring and fall ecotypes. In parts of this document the Department identifies geographically and temporally distinct groups of UKTR spring and/or fall Chinook Salmon as “population components” or “quasi-populations.” However, the Department acknowledges that, based on evidence of substantial gene flow between them, the UKTR spring and fall Chinook Salmon are ecotypic diversity components of any given combined (spring and fall) UKTR Chinook Salmon population.

4.2 Sources of Information

The Department reviewed all available data sources for this status review. Sources included literature review, the CESA listing petition, previous federal status reviews, Department and other agency reports and documents, historical and tribal reports.

The Department is fortunate to have relatively a long time-series of escapement estimates (1978 – present) for both UKTR spring and fall Chinook Salmon in the basin; however, data collection methods and other sampling features differ over time and by location. In addition, different monitoring entities may use different data collection and sampling methods. Therefore, although time-series data in the places where the majority of UKTR spring Chinook Salmon are thought to return to spawn are fairly consistent, the Department acknowledges shortcomings in sampling and data collection that may affect absolute abundance estimates and analyses based on them. However, the Department finds that the existing abundance data are the best available scientific data for status and trend evaluation over the monitoring period.

4.3 Abundance and Trend

Abundance and trend metrics were calculated using available data for UKTR spring Chinook Salmon, UKTR fall Chinook Salmon, and combined UKTR spring and fall Chinook Salmon genetic diversity groups within the basin using spawning adult estimates ranging back as far as 1978. The UKTR spring Chinook Salmon status and trend was estimated for population components in the Upper Trinity River (above Junction City Weir), South Fork Trinity River, and Salmon River. The UKTR fall Chinook Salmon status and trend are analyzed for population components in Mainstem Klamath River (excluding IGH returns), Bogus Creek, Scott River, Shasta River, Salmon River, and Mainstem Trinity River (excluding TRH returns; see Hatcheries section). Groupings based on genetic affinity include combined UKTR spring and fall Chinook Salmon elements comprising Klamath and Trinity river groups.

Some additional tributaries of the Trinity River are monitored for UKTR spring Chinook Salmon. These streams contain small numbers of fish in comparison to the three main UKTR spring Chinook Salmon aggregations. Miscellaneous monitored Trinity River tributaries include Hayfork Creek, South Fork Trinity River, Canyon Creek, North Fork Trinity River, and New River. Snorkel surveys for adult salmonids on these streams begin in mid-July and are completed by the end of August. Based on time of freshwater entry, location, and survey timing these surveys are thought to target UKTR spring Chinook Salmon. The Department leads the South Fork Trinity River snorkel survey and assists in the other tributaries. The US Forest Service (USFS) typically leads the Canyon Creek, North Fork Trinity, and New River surveys. The Hayfork Watershed Center leads the Hayfork Creek survey (Andrew Hill, CDFW, personal communication, 2020).

Data for the Klamath Tributaries from partner agencies and conservation groups can include any or all tributary creeks in both the USFS Orleans/Ukonom and the USFS Happy Camp Ranger

Districts. Reported numbers of UKTR spring Chinook Salmon in this region come exclusively from incidental sightings during the summer steelhead surveys conducted by USFS in these locations (Dan Troxel, CDFW, personal communication, 10/29/2019).

UKTR spring Chinook Salmon escapement is estimated on spawning grounds in the Upper Trinity, South Fork Trinity, and Salmon River, as well as smaller tributaries. Escapement is cooperatively estimated by a combination of tribes, agencies, and non-governmental organizations using a variety of methods including carcass surveys, weir counts, redd surveys, and mark-recapture studies (Myers et al. 1998; KRTT 2011) and at weirs by the Department, federal and tribal fishery agencies. Trap counts at both Iron Gate and Trinity River Hatcheries (shown in *Section 6.7 Hatcheries*) also contribute to overall abundance estimates. Spawning ground estimates of UKTR spring Chinook Salmon abundance can, but do not always, include both hatchery- and natural-origin spawning fish.

Similar abundance and trend metrics were calculated for UKTR fall Chinook Salmon to provide context and to help us interpret the overall abundance and trends in the combined UKTR Chinook Salmon ESU. UKTR fall Chinook Salmon population components analyzed include Bogus Creek, Mainstem Klamath River (returns to Iron Gate Hatchery omitted), Shasta River, Scott River, Salmon River, and Mainstem Trinity River (returns to Trinity River Hatchery omitted). Time series are available for these population components from about 1978 to the present with some missing years.

Time series data for both UKTR spring and fall Chinook Salmon population components prior to about 1979 are not consistently available. Therefore, available references were used to qualitatively compare current abundance and trends to those in the distant past.

Data and analyses conducted by NMFS for their original and most recent UKTR Chinook Salmon status reviews (Myers et al, 1998; Williams et al. 2011; Williams et al. 2013) were reviewed, as well as more recent data and analyses provided by scientists at NMFS Southwest Fisheries Science Center (NMFS Southwest Fisheries Science Center (SWFSC), unpublished data). Both the NMFS analyses and this status review use total adult (age > 2) spawning fish escapement estimates to characterize abundance, trends in spawning escapement, and population growth rate.

4.3.1 Abundance

4.3.1.1 Historical Abundance

Declines in salmonid abundance in the Klamath basin likely began as early as 1850 when large scale hydraulic mining was used to erode entire hillsides in search of gold. Logging in the region also increased around this time to provide building materials for gold mining operations and for building in support of a growing human population (NRC 2004).

The UKTR fall Chinook Salmon ecotype is widely distributed in the basin with upstream distribution limited by large dams. In the Klamath River drainage upstream of the Trinity River confluence, the only remaining consistent spawning aggregation of spring Chinook Salmon is in the Salmon River. Campbell and Moyle (1991) estimated annual runs ranging from 150 – 1,500 fish (but see more complete estimates in this document). In the Trinity sub-basin, a small run of spring Chinook Salmon remains in the South Fork Trinity River. A larger spawning aggregation of UKTR spring Chinook Salmon and a hatchery run exists in larger numbers in the Upper Trinity River.

Historical salmon abundance was enough to allow the Klamath River tribes to subsist largely on salmon in support of a hunter-gatherer society (Hamilton et al. 2016). Both historically and in the present day, salmon were and are a critically important cultural and nutritional foundation of Native Klamath basin tribal life.

The Department is not aware of specific quantitative assessments of historical abundance of UKTR Chinook Salmon; however, it is generally recognized that salmon runs in the Klamath basin have declined to numbers below historic levels (e.g., USDI et al. 2012; Moyle 2002). Available historical evidence (e.g., compilations by Hamilton et al. 2005; Snyder 1931; KRBFTF 1991; Lane and Lane Associates 1981) show that salmonids in the Upper Klamath basin historically contributed to large commercial, recreational, subsistence, and tribal fisheries. Likely the most important salmonid species was Chinook Salmon. Moyle (2002) estimated that UKTR spring Chinook Salmon existed at historical levels of about 100,000 spawning fish annually. The peak of UKTR Chinook Salmon (fall + spring) ESU annual abundance was estimated to be 130,000 fish based on peak cannery production of 18,000 cases of canned salmon in 1912 (Myers et al. 1998). Williams et al. (2013) note that by 1912 much of the salmonid habitat in the Upper Klamath and Trinity watersheds had been impacted by dams, mining, and other land- and water-use disturbances, suggesting that the peak historical run size above might be an underestimate. As of about 1963, the Department estimated the annual spawning escapement of UKTR spring and fall Chinook Salmon to comprise approximately 88,000 adults in the Klamath River and 80,000 adults in the Trinity River (total 168,000 adults annually; CDFG 1965). Studies by USFWS/CDFG (1956) estimated that 3,000 UKTR spring Chinook Salmon and 8,000 UKTR fall Chinook Salmon adult migrants historically passed above Lewiston Dam on the Trinity River. Some rough estimates (e.g., Moyle et al. 2017) estimate that current UKTR spring Chinook Salmon total numbers are far less than their historic abundance.

4.3.1.2 Time Series of Abundance

Raw counts of total UKTR spring Chinook Salmon returns since about 1978 are shown in Figures 4.1, 4.2, 4.3, 4.4 and 4.5. As is characteristic of salmon populations, annual variation in abundance is high and cyclic which complicates abundance and trend evaluations. Estimates of trends in abundance can be affected by where in the cycle the evaluation begins and ends. Beginning at a peak and ending at a trough will generally indicate decline, whereas starting at a trough and ending at a peak will generally result in a conclusion of population growth. To partially account for this, this analysis uses a variety of methods over long-, medium-, and short-time frames to characterize abundance status and trends. The Department has collected a relatively long time-series of data for several extant UKTR spring and fall Chinook Salmon population components.

The Trinity River Restoration Program (TRRP) sets an annual target of 6,000 naturally produced adult spawning UKTR spring Chinook Salmon system-wide. In the last five years, the TRRP goal was not met 60% of the time (Figure 4.2, 3 of 5 years). Of the remaining two years, this goal was barely met or exceeded. This contrasts with the long-term (2002 – 2018) abundance in which the goal was not met about 24% of the time. Recent UKTR spring Chinook Salmon escapement has recently been under the TRRP goal more frequently than in the past. In comparison, UKTR fall Chinook Salmon numbers in areas where UKTR spring Chinook Salmon also occur are much larger than those for UKTR spring Chinook Salmon alone between 1978 and the present (Figures 4.4). Larger UKTR fall Chinook Salmon abundance results in relatively robust raw numbers of the combined UKTR Chinook Salmon ESU over the monitoring period.

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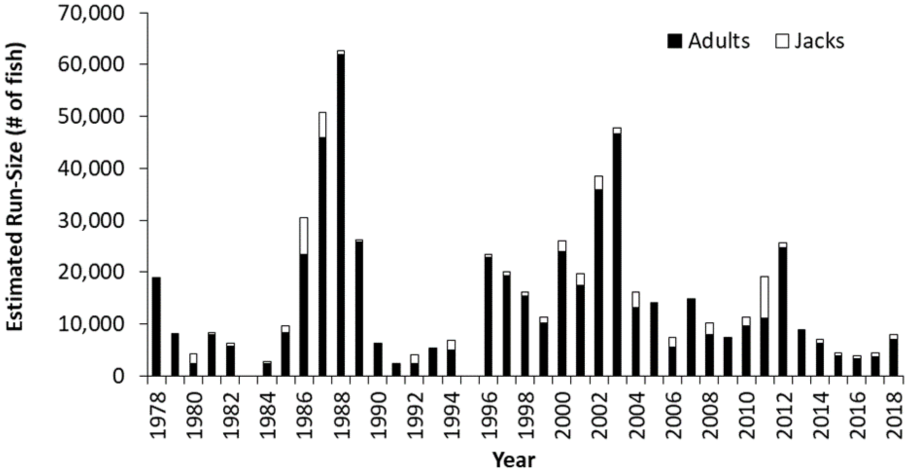

Figure 4.1. UKTR spring Chinook Salmon counts from the Upper Trinity River above Junction City Weir showing number of adults and jacks in each year. Estimates based on mark/recapture surveys. Estimates include hatchery-origin natural area spawning fish and hatchery-origin fish bound for Trinity River Hatchery.

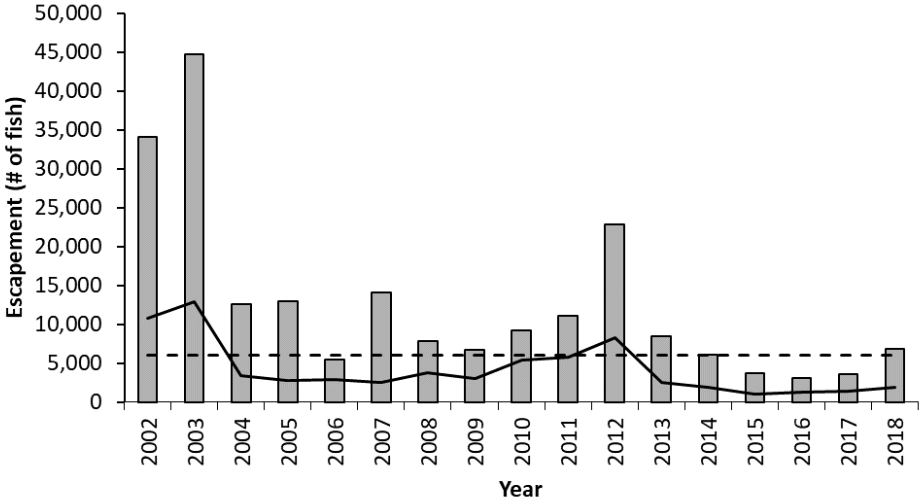

Figure 4.2. UKTR spring Chinook Salmon adult abundance for the Upper Trinity River above Junction City Weir. Solid line indicates natural origin adult estimates. Dashed line indicates Trinity River Restoration Program abundance goal of 6,000 annual spawning fish.

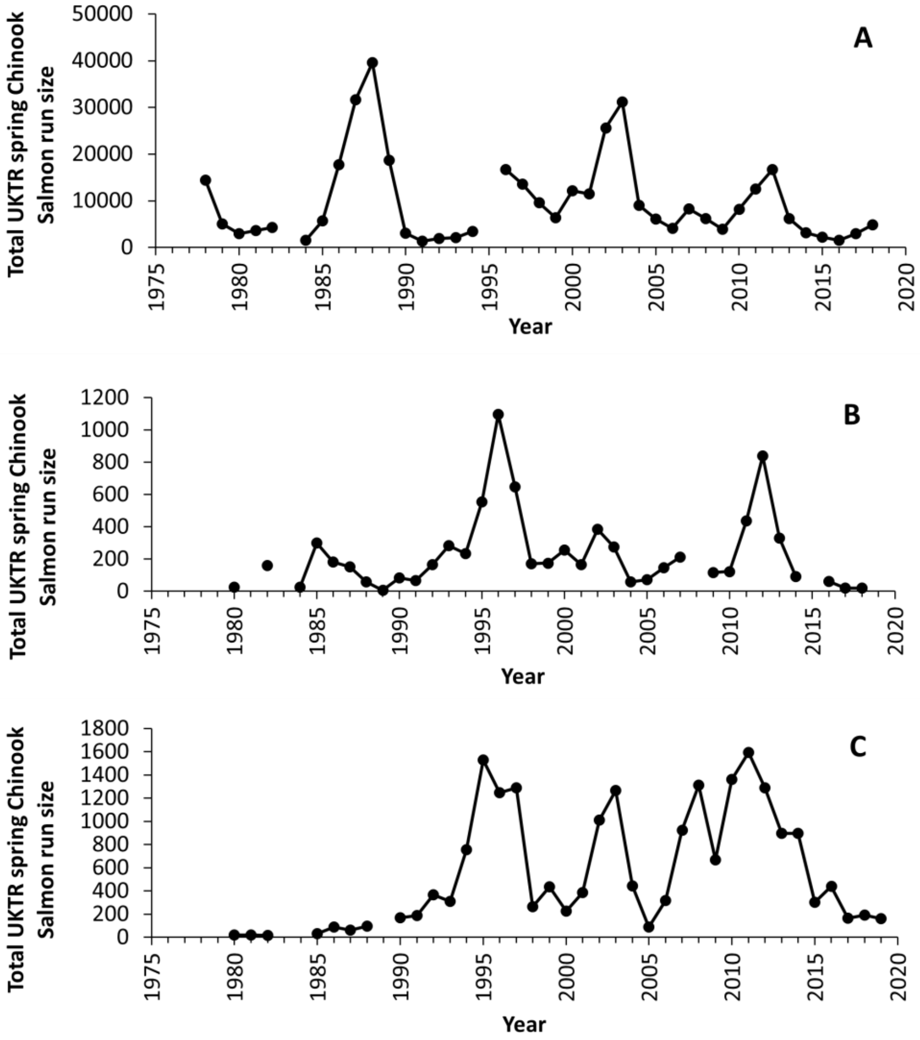

Figure 4.3. Total run-size estimates for UKTR spring Chinook Salmon population components. A. Upper Trinity River above Junction City Weir B. Salmon River, C. South Fork Trinity River,. Note different scales on the Y-axes.

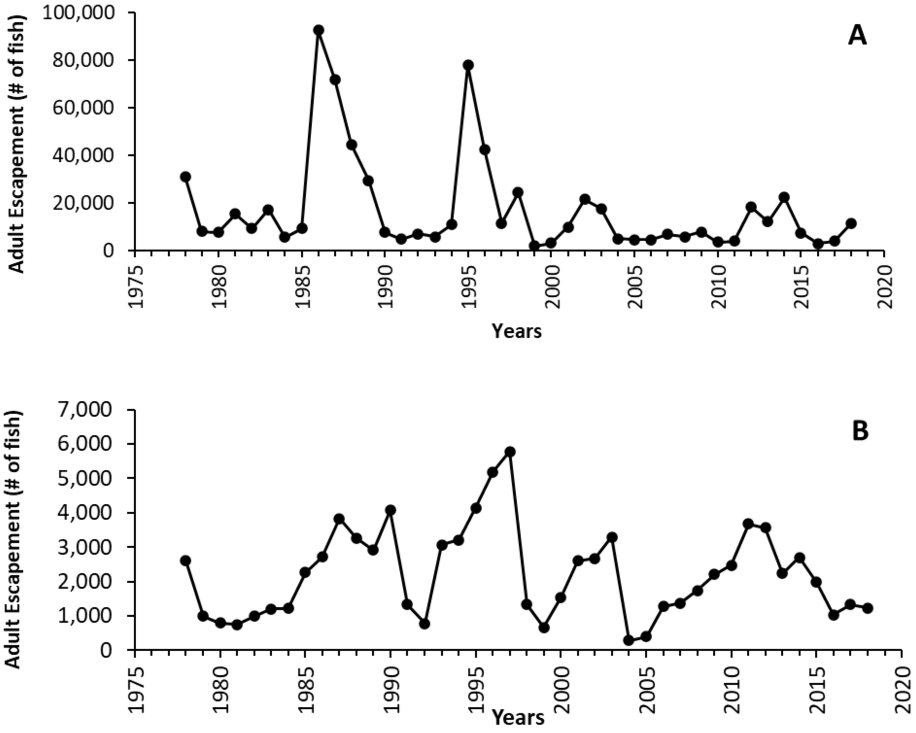

Figure 4.4. Adult escapement estimates for UKTR fall Chinook Salmon population components in A: Upper Trinity River above Willow Creek, excluding returns to Trinity River Hatchery, B: Salmon River. Note different y-axis scales.

4.3.1.3 Geometric Mean Abundance

The Department evaluated status using the best available long-term data sets. However, the Department realizes that what amounts to "historical abundance" based on records from several decades ago, while useful for evaluating status and trend over that period, may have limited use for predicting future abundance. Past escapement estimates may be less useful than recent estimates to predict current and future escapement (e.g., see *Sections 6.1 Climate Change and Potential impacts* and *7.1 Klamath Dam Removal*). For this reason, the following analysis presents long-term estimates using all data available to us while relying on more recent 12- and five-year geometric means as the best indicators of current abundance status. UKTR spring Chinook Salmon declines prior to approximately 1978 – 1980 are not reflected in the analyses below.

Because UKTR spring and fall Chinook Salmon are not reproductively isolated, and any spawning pair may have offspring with either fall or spring life history (see Genetics and Genomics), calculations of average abundance and trend by ecotype are subject to error. Although some of the following analyses attempt to correct for this, contributions of ~~Fall~~ fall Chinook to ~~Spring~~ spring Chinook numbers and trends, and vice versa, are not fully accounted for in the following analyses.

Commented [AC94]: Changes by Christian Smith

Table 4.1 shows minimum and maximum abundance estimates for the three UKTR spring Chinook Salmon population components over three time-frames—short, medium, and long. The South Fork Trinity River has the lowest values, followed by Salmon River. The Upper Trinity River minimum and maximum are moderately large; however, all maxima and minima in the short time frame are smaller than in either the medium or long-time frames. This suggests that current abundance is low in relation to past (about 30 years ago) abundance. Whether this represents a low point in the population component cycle or a new low average is not known.

Table 4.1. Minimum and maximum abundance at long-term, short-term, and medium-term time windows for the three UKTR spring Chinook Salmon population components

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	Upper Trinity River	**Salmon River**	**SF Trinity River**
Long-term			
Years	1978-2018	1995-2018	1980-2019
min	942	78	7
max	39,329	1,335	1,097
5 year			
Years	2014-2018	2015-2019	2014-2018
min	1,331	133	17
max	4,352	406	83
12-year			
Years	2007-2018	2008-2019	2007-2018
min	1,331	133	17
max	16,117	1,242	779

We evaluated abundance status using the geometric mean over long-term, using the longest running time-series available, medium-term, using data for the last four generations (12-years), and recent, using the last five years of available data, for each of the UKTR spring and fall Chinook Salmon population components. There were missing data in some of the time series noted in the following tables. Only the available data were used in the calculations, with no effort to interpolate or otherwise fill in missing data.

The geometric mean is calculated as follows:

Commented [SC95]: Consider using past tense for methods, here and throughout.

$$\bar{G} = \sqrt[n]{N_1 x\ N_2 x\ N_3 x\ N_{4\ \ldots} x\ N_n}$$

Geometric mean is a useful metric for status evaluation because it calculates central tendency of abundance while minimizing the effect of outliers in the data and is thought to more effectively characterize time series of abundance based on counts than the arithmetic average. The arithmetic average is known to be overly sensitive to a few large counts and can result in an incorrect depiction of central tendency with typically highly variable salmon population data.

In most cases, the long-term geometric mean abundance for UKTR spring Chinook Salmon spawning assemblages was greater than 12-year estimates (Tables 4.1, 4.2). The exception is the Salmon River, for which the most recent 12-year average abundance is about the same as the long-term (LT) average (LT 479, 12-yr 485). The geometric mean abundance for Upper Trinity River Springs was greatest with over 5,000 fish per year in long-term estimates and over 2,000 fish per year in recent ones (5-year averages). Salmon River Springs had a long-term annual average in the hundreds (just below 500), and a recent average around 200. The South Fork Trinity River comes in lowest with annual averages around 120 and recent 5-year averages below 50.

Table 4.2. Long-, medium-, and short-term geometric mean abundance for the three UKTR spring Chinook Salmon population components

Population component	Years	Long-term Geometric mean	Years	12-year Geometric mean	Years	5-year Geometric mean
Upper Trinity River	1978-2018[1]	5,727	2007-2018	4,394	2014-2018	2,404
Salmon River	1995-2018[2]	479	2008-2019	485	2015-2019	203
South Fork Trinity River	1980-2018[3]	126	2007-2019	106	2014-2018	34

[1] missing data 1983, 1995
[2] missing data 1996, 1998
[3] missing data 1981, 1983, 2008, 2015

UKTR spring Chinook Salmon are also found in small numbers in both Klamath and Trinity River tributaries (Table 4.3). As can be seen in the table, these counts are incomplete over the time series. This analysis used the entire data set to calculate long-term geometric mean. Due to missing data for some years, data from the last 15 years were used (five 3-yr generations) rather than our preferred 12 years (four 3-year generations) to calculate recent geometric mean (status) to include at least 10 data points in the calculation. The long-term (1980 – present) geometric mean for adult spawning fish in Klamath tributaries is very low (a few fish), and a little higher in the Trinity tributaries (tens of fish). The recent geometric mean for the Klamath tributaries is similarly very low; however, the recent geometric mean for the Trinity tributaries is a somewhat higher at 50 (adults) and 71 (adults and grilse). This may be due to hatchery fish straying into otherwise small aggregations of naturally spawning fish. UKTR spring Chinook Salmon in the miscellaneous Klamath and Trinity River tributaries contribute little to the overall numbers of UKTR spring Chinook Salmon in the basin; however, their persistent presence represents a minor part of the total range of the UKTR spring Chinook Salmon ecotype, demonstrates distribution of the spring ecotype outside of the three known spawning assemblages, and shows potential for metapopulation expansion.

Abundance of the UKTR fall Chinook Salmon ecotype was calculated for six spawning locations in the Klamath and Trinity Rivers (Tables 4.4, 4.5). The range of abundance estimates for the fall ecotype is large, ranging from hundreds to tens of thousands of fish in all time frames in all locations. Large maxima (tens of thousands) are found in the mainstem Klamath, Trinity, Scott, and Shasta rivers. Maximum fall ecotype abundance is lower (thousands of fish) in the Salmon River.

Table 4.3. Escapement of UKTR spring Chinook Salmon to miscellaneous Klamath and Trinity river tributaries, 1980 – 2019. Long-term geometric mean uses the entire data set. Recent geometric mean uses the last 5-generations (3-year generation time; 15 years) to include at least 10 data points in the calculation.

	Klamath Tributaries				**Trinity Tributaries**			
Year	**Grilse**	**Adults**	**Total**	**Grilse prop**	**Grilse**	**Adults**	**Total**	**Grilse prop**
1980						49	49	0.00
1981		4	4	0.00				
1982		5	5	0.00		8	8	0.00
1983		6	6	0.00		39	39	0.00
1984		16	16	0.00		25	25	0.00
1985		5	5	0.00		29	29	0.00
1986								
1987		2	2	0.00				
1988		8	8	0.00		273	273	0.00
1989		9	9	0.00			17	0.00
1990							33	0.00
1991							5	0.00
1992						15	18	0.17
1993							48	0.00
1994		1	1	0.00			22	0.00
1995		2	2	0.00			135	0.00
1996		2	2	0.00			73	0.00
1997							49	0.00
1998		2	2	0.00			33	0.00
1999		14	14	0.00			15	0.00
2000		6	6	0.00		16	16	0.00
2001	1	1	2	0.50	2	6	8	0.25
2002	2	2	4	0.50	10	16	26	0.38
2003		1	1	0.00	1	83	84	0.01
2004	1	2	3	0.33	5	12	17	0.29
2005	1	8	9	0.11	2	4	6	0.33
2006		1	1	0.00	42	70	112	0.38
2007					4	54	58	0.07
2008	2	5	7	0.29	5	23	28	0.18
2009	0	3	3	0.00	47	46	93	0.51
2010	0	3	3	0.00	50	180	230	0.22
2011	23	82	105	0.22	199	361	560	0.36
2012	2		2	1.00	69	358	427	0.16
2013	5	13	18	0.28	58	166	224	0.26
2014		21	21	0.00	27	105	132	0.20
2015		7	7	0.00				
2016					6	42	48	0.13
2017		2	2	0.00	2	32	34	0.06
2018	1	11	12	0.08	11	6	17	0.65
2019								

Totals	**38**	**244**	**282**		**543**	**2018**	**2991**
Geometric mean-Long-term		**4**	**5**			**38**	**42**
Geometric mean-Recent		**6**	**6**			**50**	**71**

Geometric mean abundance for the fall ecotype in all monitored locations is in the thousands to tens of thousands over all time frames (Table 4.4). The recent 5-year geometric mean is less than the long and 12-year estimates in Mainstem Trinity, Salmon, Scott rivers, and Bogus Creek. However, recent geometric mean abundance in the Shasta and Mainstem Klamath are greater than or about the same as the long- and medium-term estimates. Recent geometric means for UKTR fall Chinook Salmon are relatively large (1,500 to over 8,000), indicating low risk of immediate extinction of either the fall ecotype or the combined UKTR Chinook Salmon ESU due to the population size.

Table 4.4 Minimum and maximum adult (>2-year old) abundance at long-term, short-term, and medium-term time windows for six UKTR fall Chinook Salmon population components.

	Mainstem Trinity R.[1]	**Salmon River**	**Scott River**	**Shasta River**	**Bogus Creek**	**Mainstem Klamath R.[2]**
Long-term						
Years	**1978-2018**	**1978-2018**	**1978-2018**	**1978-2018**	**1978-2018**	**1978-2018**
Min	3,444	282	445	213	598	366
Max	92,548	5,783	11,988	27,600	45,225	22,443
5 year						
Years	**2014-2018**	**2014-2018**	**2014-2018**	**2014-2018**	**2014-2018**	**2014-2018**
Min	3,444	1,032	1,208	2,754	830	2,902
Max	23,312	2,706	10,419	18,673	12,607	22,443
12-year						
Years	**2007-2018**	**2007-2018**	**2007-2018**	**2007-2018**	**2007-2018**	**2007-2018**
Min	3,444	1,032	1,208	213	830	2,902
Max	47,921	3,674	10,419	27,600	12,607	22,443

[1] Excluding Trinity River Hatchery returns

[2] Excluding Iron Gate Hatchery returns

Table 4.5. Long-, medium-, and short-term geometric mean adult (>2-year old) abundance for six UKTR fall Chinook Salmon population components.

Population component	Years	Long-term Geo. Mean	Years	12-year Geo. Mean	Years	5-year Geo. Mean
Mainstem Trinity River[1]	1978-2018	16,134	2007-2018	15,512	2014-2018	8,149
Salmon River	1978-2018	1,817	2007-2018	1,974	2014-2018	1,554
Scott River	1978-2018	3,252	2007-2018	3,003	2014-2018	2,415
Shasta River	1978-2018	3,085	2007-2018	4,174	2014-2018	6,941
Bogus Creek	1978-2018	4,706	2007-2018	3,608	2014-2018	2,751
Mainstem Klamath River[2]	1978-2018	3,220	2007-2018	7,285	2014-2018	7,364

[1]Excluding Trinity River Hatchery returns

[2]Excluding Iron Gate Hatchery returns

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Kinziger et al. (2013) found three genetic groups of Chinook Salmon in the Klamath-Trinity: Lower River, Klamath, and Trinity groups. Of these, the Klamath Group and the Trinity Group are within the UKTR Chinook Salmon ESU. A rough estimate of the geometric mean abundance for these two groups was calculated by combining existing abundance data for both UKTR spring and fall Chinook Salmon population components in the geographic areas defined by the genetic groupings (Table 4.6).

Based on the combined abundance of UKTR Chinook Salmon in these two genetic groups, the Department's analysis found large geometric mean abundances in all time frames. This was due to the large fall ecotype component. Geometric means for both genetic groups were in the tens of thousands suggesting low risk of immediate extinction of these two groups.

Table 4.6. Long-, medium-, and short-term geometric mean adult (>2-year old) abundance for two of three UKTR Chinook Salmon genetic population groups.

Genetic Population Group	Years	Long-term Geo. mean	Years	12-year Geo. mean	Years	5-year Geo. Mean
Trinity River Group[1]	1978-2018	22,719	2007-2018	20,289	2014-2018	10,812
Klamath River Group[2]	1978-2018	19,456	2007-2018	22,978	2014-2018	22,422

[1] Trinity River Group includes: Mainstem Trinity River fall (excluding TRH returns), SF Trinity River spring, Trinity River Tributaries spring, Upper Trinity River spring above Junction City Weir.

[2] Klamath River Group includes: Mainstem Klamath River fall (excluding IGH returns), Salmon River spring and fall, Scott River fall, Shasta River fall, Bogus Creek fall, Klamath River Tributaries spring.

4.3.2 Trends in Abundance

The Department evaluated trends in abundance by calculating the slope of annual abundance over time following methods in Good et al. (2005) and Williams et al. (2011, 2013), with some modification. The Department estimated trends for all UKTR Chinook Salmon population components for which data are available using adult returns (age >2) only. The adult escapement abundance reflects trends in cohort strength of natural area spawning fish and natural area productivity. The adult escapement evaluation shows natural area return of the most productive element of the population component. Jacks, harvest, and spawning fish that return to the hatchery are not included in the following calculations. This group, however, does include hatchery-origin fish that return to natural spawning grounds. Hatchery- and natural-origin natural spawning ground returns are only estimated separately at the Junction City Weir for the Upper Trinity River population component.

Abundance trends were calculated for the three extant UKTR spring Chinook Salmon population components (Upper Trinity River above Junction City Weir, Salmon River, and South Fork Trinity River), and for six UKTR fall Chinook Salmon population components in the basin. Long-term trends were evaluated using all adult natural area return data in the available time series for each population component. The recent trend was evaluated using estimates of the annual number of natural area spawning fish for the last four Chinook Salmon generations (i.e., 12 years assuming an average 3-year generation length) with a minimum of ten data points in the series. This analysis uses four generations to calculate “recent” trend because it is close enough to the present to reflect population-level responses to current conditions while still providing enough data points (at least 10 over the 12-year period) to characterize the trend[7].

The Department estimated the trend as the calculated slope of the number of natural spawning adults over time using a linear regression performed on natural log-transformed annual counts over the time series:

$$ln(N_t) = \beta_0 + \beta_1 X + \in$$

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[7] The federal Biological Review Team in its evaluation of abundance trend expressed caution about short (recent) time series estimates due to the small number of data points in these estimates (Williams et al. 2013).

Where N_t is natural area adult spawning fish abundance, β_0 is the y-intercept, β_1 is the slope of the equation, and ε is a random error term. If necessary, one was added to all annual population size estimates prior to transformation [i.e., $ln(N_t + 1)$] to account for zeros (i.e., years in which a location *was surveyed* but no fish were found there) in the data. Missing data (i.e., years in which a location *was not surveyed*) were accounted for in the regression analysis using multiple imputation (Horton and Kleiman 2007)[8].

Trend over the time series is expressed as exponentiated slope from the regression above:

$$\exp\left(\widehat{\beta_\iota}\right)$$

with 95% confidence intervals:

$$\exp\left(\hat{\beta}_i\right) \pm t_{0.025,df}\ x\ se$$

Table 4.7 shows long-term and recent trends for the three extant UKTR spring Chinook Salmon population components. Trend values less than one indicate a decline of the average population component, whereas trend values greater than one indicate average growth. Recent adult trends for all UKTR spring Chinook Salmon population components are below one indicating across the board recent average declines in the three UKTR spring Chinook Salmon population components; however, confidence intervals for these estimates are large and, in most cases, inconclusive. Confidence intervals for recent Salmon and South Fork Trinity rivers spring Chinook Salmon support a conclusion of decline, whereas those for Upper Trinity River spring Chinook Salmon do not. The Department concludes that the UKTR spring Chinook Salmon ecotype in the Salmon River and South Fork Trinity River have likely declined in recent years.

Long term population component trends for UKTR spring Chinook Salmon show similar average declines but the trend is not supported by confidence intervals (Table 4.7).

Table 4.7. Long-term and recent trends in adult abundance (escapement) using slope of *ln*-transformed times series counts for three UKTR spring Chinook Salmon population components. Trend estimates >1 indicate average population increase over the time series, whereas those <1 indicate average decline. Long-term trends use the entire time series available for that group. Recent trends use the last 12 years (four generations) with at least 10 data points. Missing data were accounted for in the regression by multiple imputation.

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[8] Williams et al. (2013) dealt with missing data in trend regressions by simply omitting missing data years. In a limited evaluation of the two methods for this report (not shown) the two methods gave similar, though not identical numerical results; however, the trend direction and significance were the same regardless of the method used to account for missing data.

	Long-term spring (adult escapement)				Recent spring (adult escapement)			
Population component	**Years**	**Trend**	**Lower 95% CI**	**Upper 95% CI**	**Years**	**Trend**	**Lower 95% CI**	**Upper 95% CI**
Upper Trinity River above JCW[1]	1978-2018	0.9968	0.9713	1.0230	2007-2018	0.9020	0.8052	1.0104
Salmon River[2]	1995-2019	0.9709	0.9051	1.0415	2008-2019	0.8227	0.7513	0.9010
SF Trinity River[3]	1980-2018	0.9806	0.9458	1.0166	2008-2019	0.7440	0.6102	0.9072

[1] JCW = Junction City Weir. Missing data Long-term 1983, 1995

[2] Missing data long-term 1996, 1998

[3] Missing data long-term 1981, 1983, 2008, 2015; recent 2008, 2015

Average UKTR fall Chinook Salmon long- and recent-term trends (Table 4.8) for adult returns to six locations where long-term monitoring has generated annual estimates since 1978 were also calculated. Long-term average trends were less than one (declining) for fall Chinook Salmon in the Mainstem Trinity River, Scott River, and Bogus Creek. Average long-term trends were greater than one (increasing) in the Salmon River, Shasta River, and Mainstem Klamath River. However, confidence intervals for all but the Mainstem Klamath River fall Chinook Salmon range from below to above one, indicating lack of statistical support for the average trends in these population components. The trend analysis for Mainstem Klamath River fall Chinook Salmon do show statistical support for the increasing trend in this group.

Table 4.8. Long-term and recent trends in adult (>2-year old) abundance using slope of ln-transformed times series counts for six UKTR fall Chinook Salmon population components. Trend estimates >1 indicate average population increase, whereas those <1 indicate average decline. Long-term trends use the entire time series available for that group. Recent trends use the last 12 years (4 generations) with at least 10 data points.

	Long-term fall (adult escapement)				**Recent fall (adult escapement)**			
Population component	**Years**	**Trend**	**Lower 95% CI**	**Upper 95% CI**	**Years**	**Trend**	**Lower 95% CI**	**Upper 95% CI**
Mainstem Trinity River[1]	1978-2018	0.9977	0.9757	1.0203	2007-2018	0.8851	0.7695	1.0181
Salmon River	1978-2018	1.0014	0.9830	1.0200	2007-2018	0.9606	0.8911	1.0355
Scott River	1978-2018	0.9940	0.9745	1.0138	2007-2018	0.9378	0.8341	1.0545
Shasta River	1978-2018	1.0057	0.9770	1.0352	2007-2018	1.1505	0.9063	1.4603
Bogus Creek	1978-2018	0.9997	0.9747	1.0254	2007-2018	0.9356	0.8153	1.0736
Mainstem Klamath River[2]	1978-2018	1.0580	1.0341	1.0824	2007-2018	1.0114	0.8902	1.1491

[1] Excluding Trinity River Hatchery
[2] Excluding Iron Gate Hatchery

Recent fall Chinook Salmon population component trends showed average declines in the Mainstem Trinity River, Salmon River, Scott River, and Bogus Creek. A recent increasing average trend was observed in UKTR fall Chinook Salmon returning to the Shasta River and the Mainstem Klamath River; however, there was no statistical support for any of these recent average trends.

Lastly, Kinziger et al. (2013) found three genetically defined groups of Chinook Salmon in the Klamath-Trinity basin: Klamath River, Trinity River, and Lower River. Of these, the Klamath and Trinity river groups are within the geographic boundaries of the UKTR Chinook Salmon ESU. The Lower River group is included in the Southern Oregon and Coastal Chinook Salmon ESU and, therefore, is not a part of this review.

Because the UKTR spring Chinook Salmon are an ecotype of the larger UKTR Chinook Salmon ESU, the Department calculated trends for these two more inclusive genetically defined groups (Table 4.9). To do this, the estimated number of annual UKTR spring and fall Chinook Salmon from each location where monitoring is conducted were added together. Adding the available data in this way is not ideal because it does not account for intrinsic sampling bias or differences in sampling method or period; however, it is the only option for evaluating the combined spring and fall ecotype components as genetically defined units with the available data.

Table 4.9. Long-term and recent trends in adult (>2-year old) abundance using slope of *ln*-transformed times series counts for the two UKTR Chinook Salmon genetic population groups (combined spring and fall; Kinziger et al. 2013). Trend estimates >1 indicate average population increase, whereas those <1 indicate average decline. Long-term trends use the entire time-series available for that group. Recent trends use the last 12 years (4 generations) with at least 10 data points.

	Long-term (adult escapement)				**Recent (adult escapement)**			
Genetic Population Group	**Years**	**Trend**	**Lower 95% CI**	**Upper 95% CI**	**Years**	**Trend**	**Lower 95% CI**	**Upper 95% CI**
Trinity River Group[1]	1978-2018	0.9978	0.9759	1.0202	2007-2018	0.8894	0.7798	1.0144
Klamath River Group[2]	1978-2018	1.0141	0.9961	1.0325	2007-2018	1.0076	0.8926	1.1374

[1] Trinity River Group includes: Mainstem Trinity River fall (excluding TRH returns), SF Trinity River spring, Trinity River Tributaries spring, Upper Trinity River spring above Junction City Weir.

[2] Klamath River Group includes: Mainstem Klamath River fall (excluding IGH returns), Salmon River spring and fall, Scott River fall, Shasta River fall, Bogus Creek fall, Klamath River Tributaries spring.

When treated as two separate populations, the trend for the Trinity River Group was less than one (declining) and that for the Klamath River Group was greater than one (increasing) over both the long term and recent monitoring periods; however, as in other sections of this analysis, there was no statistical support for either trend.

4.5.3 Productivity

We evaluated productivity of the UKTR spring and fall Chinook Salmon population components by evaluating cohort replacement rate over time. Cohort Replacement Rate (CRR) expressed as *ln*(CRR) is:

$$ln\,(CRR) = ln\left(\frac{N_{t+3}}{N_t}\right)$$

Natural log transformed CRRs > 0 indicate that the cohort increased in size that year in relation to the brood year three years earlier, whereas *ln*(CRR) < 0 indicates that it declined over that generation. This analysis assumes a generation time for UKTR Chinook Salmon of three years, which is reasonable for the species. The Department's analysis used adults only for the CRR calculations to better meet the three-year generation time assumption. Gaps in the graphs below are due to years without data (Figures 4.5, 4.6, 4.7).

For the entire available time series, *ln*-CRRs for the three UKTR spring Chinook Salmon population components show about as many "less than replacement" as "greater than replacement" years (Figure 4.5). However, looking at recent years, the Salmon River population component exhibits *ln*-CRRs below zero from 2013 – 2019 spawning years. Both Upper Trinity River and South Fork Trinity River population components show declines in recent years, but an upturn was noted in 2019, which might be expected given the cyclic nature of the long-term trend.

Cohort replacement rates for UKTR fall Chinook Salmon show a similar pattern of growth and decline years in cyclic clusters (Figures 4.6, 4.7). Over the entire time series (about 1980 – 2019), there are approximately the same number of positive as negative *ln*(CRR)s for all fall population components. Recent years are in a decline phase that lasts between about 2013 – 2017. This is similar to the *ln*(CRR) pattern observed in the UKTR spring Chinook Salmon population components, suggesting that the spring and fall elements are experiencing similar environmental conditions and responding similarly to them. Drought conditions across California 2014 – 2017 are correlated with these low *ln*(CRR)s. Cohort replacement rates for four of the six fall population components show increases in 2018 or 2019. This pattern of a decline phase of about 2 – 5 years followed by an increase phase for several years is a typical pattern for anadromous salmonid populations. The most recent year *ln*(CRR) for Salmon and Scott River fall Chinook Salmon continues the decline phase, unlike other fall population components. It is unknown whether less than replacement *ln*(CRR)s will continue in the future, or whether they will show delayed improvement as in the previous pattern.

Overall, both UKTR fall Chinook Salmon and UKTR spring Chinook Salmon population components of the combined UKTR Chinook Salmon ESU show similar patterns of cohort replacement rates. They show similar cycles of positive and negative values in most cases. Recent *ln*(CRR)s for all population components are "less than replacement" with an upturn in 2018 – 2019 in most cases. The Salmon River UKTR spring Chinook Salmon population component remains below replacement.

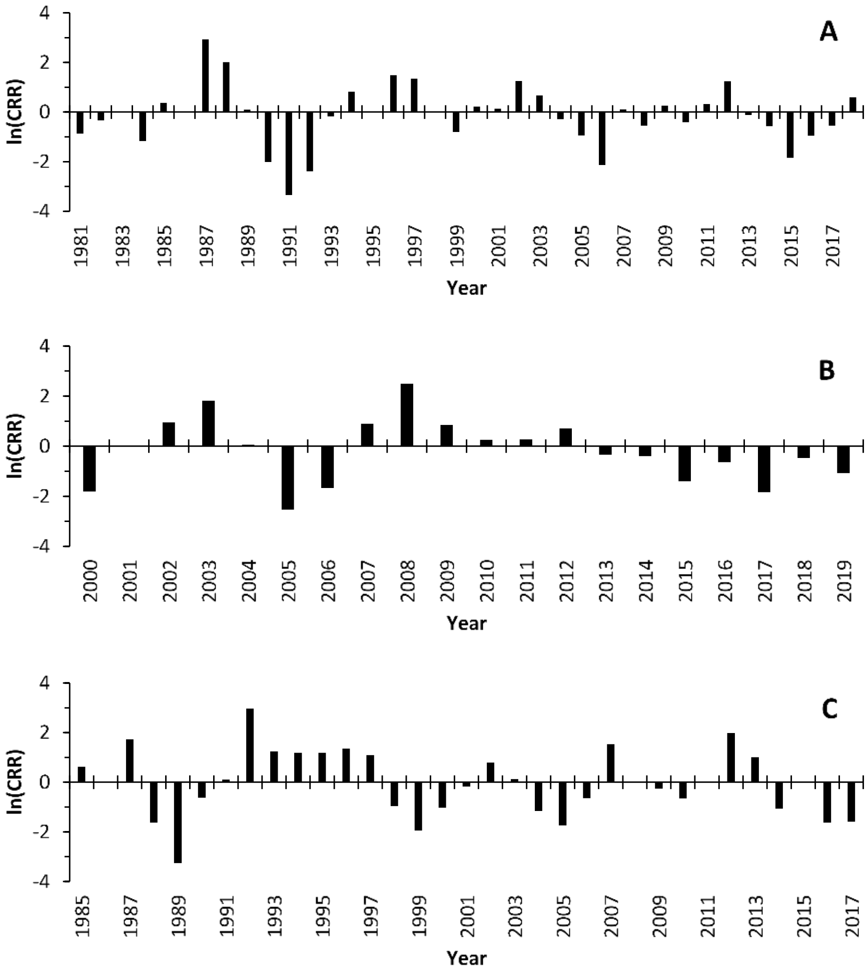

Figure 4.5. Natural log-transformed Cohort Replacement Rates (*ln*CRR) for the three UKTR spring Chinook Salmon population components of UKTR Chinook Salmon ESU: A) Upper Trinity River, B) Salmon River, and C) South Fork Trinity River. Data are adult natural area spawning fish only. Differing X-axis ranges and gaps are due to years with missing data.

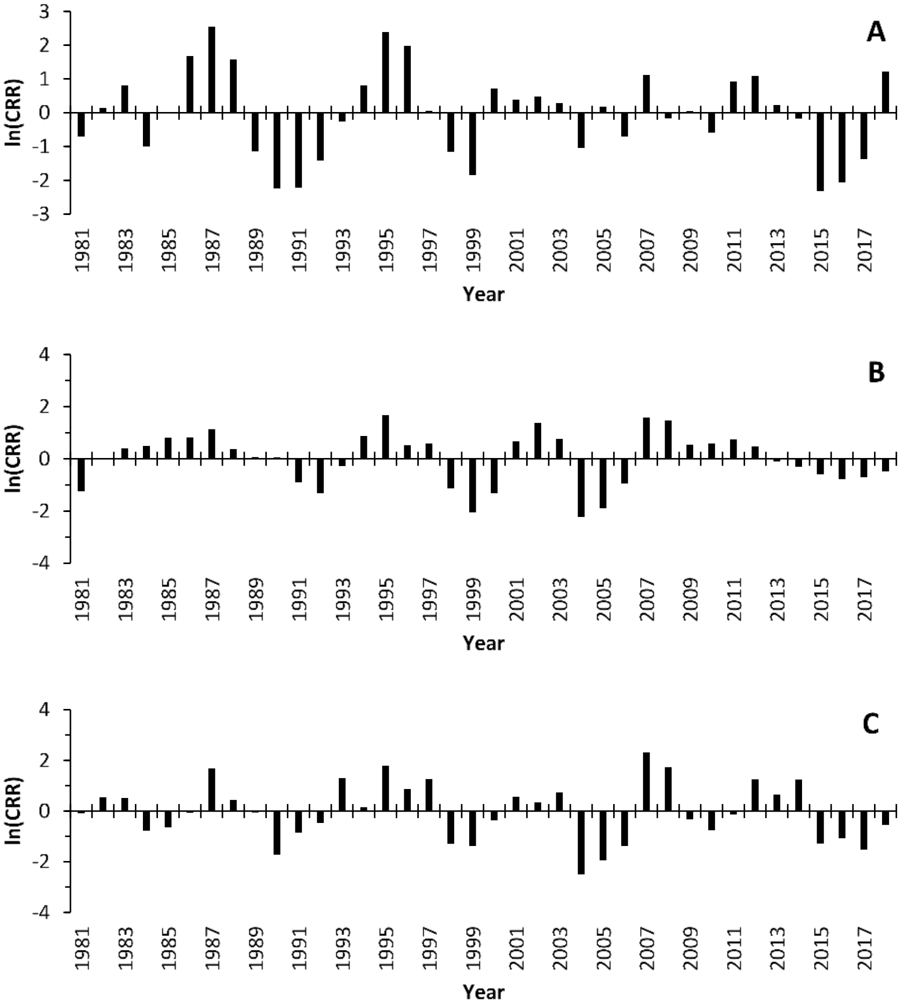

Figure 4.7. Natural log-transformed Cohort Replacement Rates (*ln*CRR) for three fall population components of UKTR Chinook Salmon ESU: A) Mainstem Trinity River (excluding Trinity River Hatchery returns), B) Salmon River, C) Scott River. Data are adult natural area spawning fish only. Gaps are due to years with missing data.

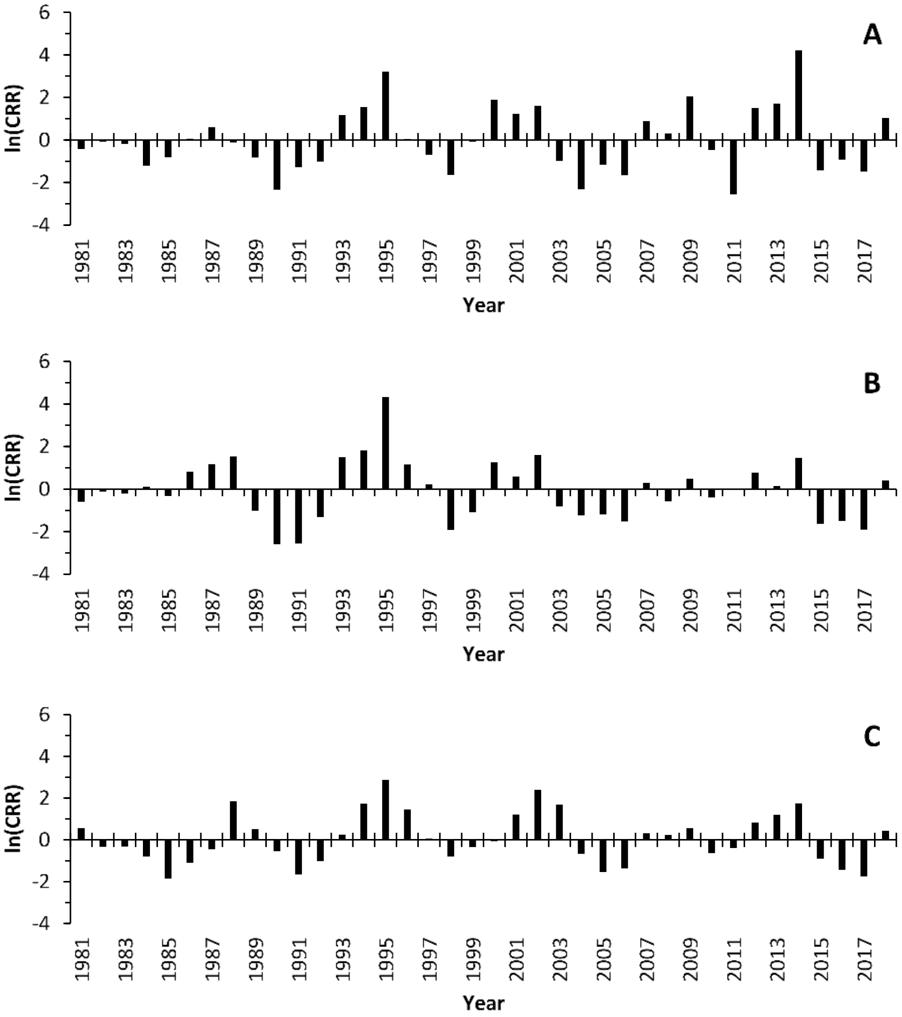

Figure 4.8. Natural log-transformed Cohort Replacement Rates (*ln*CRR) for three fall population components of UKTR Chinook Salmon ESU: A) Shasta River, B) Bogus Creek, and C) Mainstem Klamath River (excluding Iron Gate Hatchery Returns). Data are adult natural area spawning fish only. Gaps are due to years with missing data.

4.4.4 UKTR Chinook Salmon ESU (Spring and Fall Population Components) Growth Rate

In their ESA status review of UKTR Chinook Salmon, Williams et al. (2013) presented growth rate calculations for nine UKTR spring and fall Chinook Salmon population components (Table 4.10). Growth rate was calculated using the methods of Dennis et al. (1991) and Good et al. (2005). Growth rate (lambda; λ), can be used to evaluate population growth or decline: $\lambda < 1$ indicates decline, $\lambda > 1$ indicates growth over the time series analyzed. These calculations assume that the populations being analyzed are sufficiently isolated from one another such that their persistence trajectories are distinct. It is likely, however, that the population components of the UKTR Chinook Salmon ESU have considerable overlap; therefore, these results should be interpreted carefully.

Growth rate, commonly called the “finite rate of population increase” (or “per individual growth rate”), is calculated over a single time step (usually, but not necessarily, one year) as:

$$\lambda = N_{t+1}/N_t$$

Where N is the census number each year t. Growth rate is the change in number of individuals observed in successive years (or other time periods).

To reduce the effects of process and measurement errors in the annual survey data, Williams et al. (2013), following Good et al. (2005), used four-year running sums of annual adult escapement estimates, rather than the sequence of annual estimates in one-year time steps (McClure et al. 2003, Good et al. 2005). The four-year running sums were calculated as:

$$R_t = \sum_{i=0}^{3} N_{t-1}$$

Estimates of mean (μ) and variance (δ^2) of successive four-year running sums are calculated as:

$$\hat{\mu} = mean\left\{ln\left(\frac{R_{t-1}}{R_t}\right)\right\}$$

$$\hat{\delta}^2 = var\left\{ln\left(\frac{R_{t-1}}{R_t}\right)\right\}$$

These estimators correspond to the average slope (μ) and variance (δ^2) of the series of four-year running sums of annual abundance for each population component over the time series available.

Using the above estimators of mean (μ) and variance (δ^2), growth rate can be calculated as:

$$\lambda = \exp\left(\hat{\mu} + \frac{\delta^2}{2}\right)$$

Adding one-half the variance to the average of successive ratios of *R* results in an unbiased estimate of λ (Dennis et al. 1991). Note that if the variance is large in relation to the mean, even negative values of μ can give positive estimates of λ.

Confidence intervals were calculated as in Dennis et al. (1991; Equation 68):

$$exp\left[\tilde{r} \pm z_{\alpha/2}\sqrt{\tilde{\delta}^2\left(\frac{1}{t_q} + \frac{\tilde{\delta}^2}{2(q-1)}\right)}\right]$$

Except for the Upper Trinity River spring Chinook Salmon, all other long-term growth rate estimates are above one, indicating average growth over the long-term time frame (Table 4.10); however, confidence intervals for all estimates bracket one indicating uncertainty about the direction of population component trajectory. The declining growth rate estimate for the Upper Trinity spring Chinook Salmon was complicated by missing data that forced the analysis to include a shorter time frame than desired. The long- and recent- time frames for this population component are similar — they may not really represent different time frames.

The short-term growth rates for four of the six fall Chinook Salmon population components (Upper Klamath, Scott, Salmon, and Upper Trinity rivers) were above one, indicating average growth. Trend for Bogus Creek should be interpreted with caution because it is heavily influenced by returns of fall ecotype fish to Iron Gate Hatchery. Two of the six (Bogus Creek and Shasta River) were below one (declining). Growth rate estimates for the Upper Trinity and South Fork Trinity River spring Chinook Salmon was below one, but for Salmon River was above one; however, as for the long-term estimates, all confidence intervals bracketed one, indicating high uncertainty about the actual growth rate for the both spring and fall Chinook Salmon population components.

As reported in Williams et al. (2013), the federal Biological Review Team (BRT) concluded, using this and other analyses (not shown), that there had been little change in growth rate since the review of Myers et al. (1998); however, the BRT noted that current abundance levels of some populations are low, both absolutely and in historical context. The BRT noted specifically that Salmon River and South Fork Trinity River spring Chinook Salmon had low recent abundance below 1,000 fish annually.

Table 4.10. Growth rate (λ) calculations for nine UKTR spring and fall Chinook Salmon population components. From: Williams et al. 2013, Table 2 (Original data from Pacific Fishery Management Council 2011, Appendix B; CDFG 2011a, CDFG 2011b); methods described by Good et al. 2005.

		Long-term				Short-term			
Population Component	**Eco-type**	**Years**	**λ**	**Upper 95% CI**	**Lower 95% CI**	**Years**	**λ**	**Upper 95% CI**	**Lower 95% CI**
Bogus Creek	Fall	1978-2010	1.140	0.935	1.391	1998-2010	0.902	0.755	1.077
Up. Klamath R.	Fall	1978-2010	1.101	0.956	1.267	1998-2010	1.102	0.866	1.402
Shasta River	Fall	1957-2010	1.052	0.949	1.166	1998-2010	0.990	0.781	1.255
Scott River	Fall	1978-2010	1.037	0.939	1.146	1998-2010	1.009	0.821	1.240
Salmon River	Fall	1978-2010	1.049	0.953	1.155	1998-2010	1.076	0.877	1.320
Upper Trinity R.	Fall	1978-2010	1.114	0.942	1.316	1998-2010	1.010	0.905	1.128
Salmon River	Spring	1990-2010	1.133	0.962	1.335	1998-2010	1.154	0.959	1.388
Upper Trinity R.	Spring	1996-2010	0.962	0.799	1.157	1998-2010	0.976	0.776	1.229
SF Trinity River	Spring	1985-2011	1.056	0.899	1.239	1999-2007	0.880	0.728	1.065

4.5.6 Diversity

UKTR spring Chinook Salmon are a diversity element (an ecotype) within a larger interbreeding group containing more numerous UKTR fall Chinook Salmon. Together these comprise the UKTR Chinook Salmon ESU. Current assessments indicate that the allele associated with spring migration timing is not common in some portions of the range, but may be more common in others, and that these alleles can be found in the heterozygous condition (Thompson et al. 2019; Anderson et al. 2019; Anderson and Garza 2019). Although UKTR spring Chinook Salmon groups are fragmented and at low numbers, the spring ecotype could regenerate from existing genetic variation if conditions favoring the spring life-history type were to improve and expand in the basin.

4.6 Conclusions: Status and Trend

4.6.1 Status

Although historical numbers are not specific or well documented, it is qualitatively clear that the UKTR Chinook Salmon ESU was much larger in the historical past than today. The UKTR spring Chinook Salmon ecotype, although once perhaps the largest portion of total Chinook Salmon returns to the Klamath-Trinity system, have declined substantially, and disproportionately, in comparison to both historical ESU abundance and UKTR fall Chinook Salmon abundance.

Adult escapement estimates for UKTR spring Chinook Salmon from 1979 to the present are highly variable ranging from low to moderately high (1000s) depending on the population component. Recent UKTR spring Chinook Salmon geometric mean abundance (5-years) is lower than longer time period estimates for all population components. Recent geometric mean abundance for UKTR spring Chinook Salmon in the Salmon River (100s), and especially in the South Fork Trinity River (10s) are low. In contrast, the UKTR spring Chinook Salmon ecotype in the Upper Trinity River persist at much higher average numbers (1,000s). Although there is evidence that the spring ecotype is in decline in at least two of the three extant locations, the larger combined UKTR Chinook Salmon ESU is not.

UKTR fall Chinook Salmon geometric mean abundance has declined, but recent estimates for all spawning aggregations are still in the 1,000s of fish. When UKTR spring and fall Chinook Salmon population components are combined into genetic groups, comprising both ecotypes over a larger number of surveyed sites, their geometric means are in the 10,000s. Similarly, the UKTR Chinook Salmon ESU overall geometric mean abundance is in the 10,000s, which indicates that the threat of extinction for the UKTR Chinook Salmon ESU is low.

4.6.2 Trend

When evaluated as their own “species” or “populations” adult return trends of UKTR spring Chinook Salmon show weak evidence of decline for all three population components over the long-term monitoring period; however, confidence intervals for these average trend estimates range from below to above one. Therefore, the Department cannot conclude that long-term declines over the monitoring period have occurred with certainty.

Recent trends for returning adult Salmon River and South Fork Trinity River UKTR spring Chinook Salmon population components are stronger, showing statistically supported declines over the last four generations (12 years). On average, naturally spawning populations comprised of spawning spring Chinook Salmon adults seem to have declined in these two groups, with stronger evidence for declines in the two smallest (least abundant) population components in recent years.

However, UKTR spring Chinook Salmon are only one of two (along with fall) ecotypes of the combined UKTR Chinook Salmon ESU that are connected by gene flow. Looking at trends in the connected UKTR fall Chinook Salmon component shows a combination of positive and negative trends over the time periods analyzed. Only the long-term average growth of the Mainstem Klamath UKTR fall Chinook Salmon group is supported statistically.

When available UKTR spring and fall Chinook Salmon escapement estimates are aggregated into genetically defined groups, only weak evidence for declines is observed in the Trinity River Group with a lack of statistical support for the trend in either group.

Overall, the Department finds that most trends in UKTR Chinook Salmon, regardless of how they are grouped, show uncertainly weak decline in some places over some time periods. There is better evidence in the monitoring data of recent (12-year) declines in UKTR spring Chinook Salmon in the Salmon River and the South Fork Trinity River.

4.6.3 Productivity

Overall, UKTR spring Chinook Salmon population components show about as many “above replacement” as “below replacement” years since about 1979. The Upper Trinity River and South Fork Trinity River spring Chinook Salmon show recent below replacement years, but with an upturn in 2019. However, UKTR spring Chinook Salmon in the Salmon River have been at less than replacement for an extended period (2013 – 2019) without a recent upturn.

UKTR fall Chinook Salmon population components show similar cycling of CRRs to that of UKTR spring Chinook Salmon. Both fall and spring ecotypes show similar recent low productivity, suggesting that they are responding to similar environmental conditions. The 2014 – 2017 drought likely had a strong effect on productivity of the UKTR Chinook Salmon ESU as a whole.

4.6.4 Growth Rate

Williams et al. (2013) concluded that there had been little change in growth rate for the UKTR Chinook Salmon ESU since the original evaluation in Myers et al. (1998). There are no data prior to ~~that~~ those used by Myers et al. (1998) to compare recent with historical growth rates.

Commented [AC96]: Changes by Christian Smith

4.6.5 Diversity

Taken as a whole, the UKTR Chinook Salmon ESU retains fish that express both spring and fall returning phenotypes and heterozygotes carrying both spring and fall alleles are present in the system; however, UKTR spring Chinook Salmon in the Salmon River and South Fork Trinity River remain at low numbers. Genetic evidence suggests that the spring ecotype could be regenerated by existing fish heterozygous for the “spring allele”, if and when conditions favoring the spring ecotype become available.

Commented [SN97]: This is not likely. It would probably require stock transfers to restore the spring ecotype to adequate numbers if lost

Commented [SC98]: In general, I believe this section is very well supported. My reading of the available data is that the spring ecotype has declined, likely in response to selection (i.e., anthropogenic restriction of available habitat for successful expression of the spring life history type as it has existed within this ESU). I believe this last sentence is true, but optimistic: the other side of this statement would be along the lines of “if anthropogenic restriction of the necessary conditions continues indefinitely, then eventual loss of this “spring allele” due to drift is very likely.

5. Habitat Essential for Continued Existence of the Species

5.1 Adult Migration

Potential factors that influence migratory behavior of UKTR spring Chinook Salmon in the Klamath basin include discharge, water temperature, dissolved oxygen levels, and access to holding areas and tributary streams. Historically, returning adult migrants entered the Klamath River estuary in March (Snyder 1931), but contemporary river entry now appears to commence in April. Peak arrival in the estuary, based on angler catch data obtained during creel surveys, is mid-June to mid-July ending in mid-August (Troxel 2018). Unlike smaller coastal streams, the Klamath River rarely loses connection to the ocean due to sand bar formation, but if it does, it rarely remains a barrier to adult migration for more than a day or two. In addition, river mouth closures typically occur in late summer/early fall when instream flow is at its lowest and after UKTR spring Chinook Salmon have entered the system. Therefore, adult entry into the Klamath River by UKTR spring Chinook Salmon does not appear to be constrained by river mouth blockages.

Returning spawning fish migrate to holding or spawning areas primarily during daylight, though it is not clear why (Neave 1943). Strange (2010) studied the migration behavior of fall Chinook Salmon in the Klamath River and found that elevated temperatures strongly affect migratory behavior. As temperatures reach stressful levels fish begin to seek thermal refugia to reduce metabolic demand, quickly migrating between thermal refugia as they move upstream (Strange 2012). A daily mean temperature of 23° C, a mean weekly temperature of 22° C, or a maximum weekly temperature of 23° C are thought to be complete migration barriers to adult Chinook Salmon in the Klamath River (Strange 2012). River temperatures during the Klamath River entry and migration of UKTR spring Chinook Salmon (April – August) ranges between 8-26° C[9].

Stream temperature is the most critical habitat element associated with UKTR Chinook Salmon migration in the Klamath River. Ambient stream temperatures dictate migration rates, holding times, susceptibility to disease, gonadal maturation, metabolic processes, and pre-spawn mortality rates (Strange 2010, Marine and Cech 2004, CDFW 2004).

5.2 Summer Holding

Chinook Salmon complete their migration when they find suitable holding areas, generally in upstream reaches of mainstem rivers or tributaries (Moyle 2002). Holding primarily occurs in deep water with cover provided by boulders, rock outcroppings, aquatic vegetation, or surface

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[9] Department of Water Resources, California Data Exchange Center, http://cdec.water.ca.gov/dynamicapp/QueryF?s=knk

turbulence (NRC 2004). Large pools may assume greater importance for summer holding in low water years due to potential for pool stratification and suitable temperatures, whereas in higher water years temperatures may be suitable across a range of pool volumes and habitat types (Barnhart and Hillemeier 1994). When temperatures are suitable across habitat types (e.g., pools, runs and glides), holding adult spring Chinook Salmon tend to be more widely and evenly distributed. When temperatures are more heterogenous with areas of stressful or higher temperatures (e.g., in low water years), holding spring Chinook Salmon are more associated with pools (Barnhart and Hillemeier 1994, Torgersen et al. 1999). High pre-spawn mortality has been observed among holding adult UKTR spring Chinook Salmon when daily average temperatures were greater than 21° C for more than a few days (Williams 2006).

5.3 Spawning

Commented [SN99]: This section lacks temporal details on general spawn timing

Habitat necessary for successful UKTR spring Chinook Salmon spawning is characterized by appropriate thermal regimes and dissolved oxygen levels (pre-spawn holding and spawning), proper stream depth and velocity and adequate physical properties of the stream bed (gravel and fine sediment composition) for redd construction. In addition, prime spawning habitat will have proximity to escape cover, deep pools, large woody debris, or stream-morphological characteristics such as undercut banks.

Suitable depths and velocities for redd construction seem to vary widely (Healy 1991), but most spawning seems to occur at depths of 25 – 100 cm and velocities of 30 – 80 cm/sec (Moyle 2002). Extensive observations in the Trinity River documented that most Chinook Salmon spawning is at depths ranging from 15 – 76 cm and velocities ranging from 23 – 76 cm/sec (Hampton 1997). Spawning gravel size varies considerably as Chinook Salmon have been observed spawning in gravel with a median diameter ranging from 11.2 – 78.0 mm (Kondolf and Wolman 1993). However, Platts et al. (1979) report that Chinook Salmon preferentially select gravel ranging from 7 – 20 mm. Redds are constructed by females, and the size of spawning gravel scales with the female body size (Kondolf and Wolman 1993).

Intergravel water flow, which provides dissolved oxygen for developing eggs and removes metabolic wastes, is a key feature guiding redd site selection. Intergravel flow may play a more important role in spawning site selection than water depth or velocity (Healey 1991).

Microhabitat selection for redd construction based on physical parameters of water depth, water velocity, substrate size, temperature, and other factors are clearly important, but physical access to suitable habitat in the historic distribution of UKTR spring Chinook Salmon (e.g., upstream of dams) is also critically important. Historically, UKTR spring Chinook Salmon spawning was likely more temporally and spatially segregated from UKTR fall Chinook Salmon, which played an important role in maintaining the distinctness between the two runs by reducing interbreeding (Williams 2006).

5.4 Egg and Larval Development

Developing eggs require dissolved oxygen levels of at least 5.0 mg/l, with survival increasing with as oxygen levels approach saturation; however, dissolved oxygen alone does not appear to be sufficient to maintain high survival of eggs. Good intergravel flow is also required. Even at saturated oxygen levels, reduced intergravel flows have been found to reduce survival (Shumway et al. 1964, as cited in Reiser and Bjornn 1979). While decreased flow is generally associated with decreased dissolved oxygen, when oxygen levels are sufficient to support growth and survival of eggs, flow is also needed, presumably, to remove metabolic waste (Reiser and Bjornn 1979). In order to maintain sufficient intergravel flow, spawning gravels should have less than 25% fines (≤ 6.4 mm), though less is better (Reiser & Bjornn 1979).

5.5 Fry Emergence

After hatching, UKTR spring Chinook Salmon alevins may live in gravel for 4 – 6 weeks prior to emergence, usually until the yolk sac is fully absorbed (Moyle et al. 2015). The alevin life-stage is generally less susceptible than eggs to suboptimal temperature and dissolved oxygen levels, as they can move short distances within the gravel to escape poor conditions. However, temperatures higher than optimal water temperatures or other suboptimal inter-gravel conditions can result in premature emergence in salmonids (e.g., Beer and Steel 2018, Fuhrman et al. 2017). When fish emerge prior to complete yolk sac absorption, the yolk sac can interfere with locomotion and orientation (Thomas et al. 1969), making them more susceptible to predation (Fresh and Schroder, 1987).

Emerging fry require similar habitat characteristics as the egg and larval life-stages, including gravel substrate with adequate intergravel flow and water quality and suitable water temperature and dissolved oxygen. Even if embryos hatch and develop, fry survival may be poor if they are prevented from emergence by excessive amounts of sand and silt in the gravel (Reiser and Bjornn 1979). Although field evidence looking specifically at fry emergence is sparse, laboratory studies have found that Chinook Salmon emergence is impacted when sediments less than 6.4 mm in diameter made up more than 20% of the substrate (Bjornn 1969 and McCuddin 1977, as cited in Reiser and Bjornn 1979). Emergent fry experience higher survival if high quality rearing habitat is nearby and accessible (Chamberlain et al. 2012).

5.6 Juvenile Rearing and Emigration

Juvenile UKTR spring and fall Chinook Salmon are difficult to visually differentiate in the Klamath and Trinity rivers due to variability in spawn timing and developmental rates, so most field studies simply characterize juvenile Chinook Salmon habitat broadly rather than distinguishing requirements of the spring and fall ecotypes. Younger, smaller fish rely more heavily on shallow water closer to stream margins and cover. As they grow older and larger, they take advantage of deeper water and higher velocities while having less reliance on cover (Allen 2000). Goodman et al. (2010) performed an extensive observational study of fry and presmolt habitat preferences in the Trinity River finding that optimal habitat for fry included depths less than 0.61 m, velocities less than 0.15 m/sec, and distances to cover of less than 0.61 m. Those values increased to less than 1.0-meter depth, velocities less than 0.24 m/sec, and distances to cover of less than 0.61 m. Cover included aquatic or overhanging vegetation, woody debris, or boulders. Juvenile Chinook Salmon in other locations also use floodplain and off-channel waters when available to capitalize on increased prey densities and warmer temperatures compared to that in the mainstem (Sommer et al. 2001). In mainstem rivers like the Klamath, where temperatures during the juvenile rearing season reach stressful or lethal levels and diseases are present, thermal refugia ≥2° C cooler than mainstem temperatures can decrease vulnerability to disease (Chiaramonte et al. 2016).

5.7 Estuaries

The Klamath River estuary is relatively small in relation to the large size of the watershed. Tidal influence only extends to about rkm 6.5 (RM 4.0) during typical high tides with saltwater intrusion ranging from only 4 to 6 km (2.5 – 3.7 miles) upstream of the mouth. Because of its small size, the Klamath River estuary does not provide the level of ecological services to the extent that larger estuaries do (e.g., presence of large tidal marshes and flats); however, the Klamath estuary does provide nursery and rearing habitat for many fish species and is a critical staging area for anadromous fish migrating between ocean and freshwater. These areas are essential transition zones for out-migrating juvenile and returning adult Chinook Salmon and other salmonids.

Annual precipitation in the Klamath basin is approximately 200 cm, resulting in large seasonal freshwater inputs to the Klamath estuary and coastal waters. Freshwater inputs, habitat-forming processes, habitat quality (e.g., hydrologic processes, water quality, and nutrient transport) and sediment transport are strongly affected by reduced and managed flows due to dams in the region and other anthropogenic activities. Estuaries and bays are especially vulnerable to coastal development, pollution, invasive species, and coastal fishing.

Also because of its size, and the presence of a sandbar at the river's mouth, the Klamath estuary is "river-dominated" having limited coastal exchange. Foraging habitat for anadromous juveniles is found in associated wetlands, sloughs, and off-channel waters. For example, juvenile salmonids use beaver ponds in small tributaries as seasonal rearing habitat. Coastal environments are also affected by Klamath River flows through the estuary to the nearshore ocean. Physical processes mediated by river flows affect creation of reefs and outcroppings, rocky intertidal zones, and sandy beaches along the nearby coast (Thorsteinson et al. 2011).

6. Factors Affecting the Ability to Survive and Reproduce

Numerous published evaluations and summaries (e.g., NRC 2008; Stanford et al. 2011; USDI et al. 2012; NMFS 2013) describe stressors impacting UKTR Chinook Salmon habitat and biological modifications in the Klamath basin. Stressors include habitat loss due to dam construction and operation, reduced flows, presence of drainage infrastructure and canals, loss of wetlands, and increases in nutrient and sediment inputs. This section describes the major factors that affect the ability of UKTR spring and fall Chinook Salmon to survive and reproduce. The section also considers potential future impacts of climate change and ocean conditions.

6.1 Dams and Diversions

Dam construction and operation, along with land and water use practices, have fragmented populations and degraded habitat quality in the Klamath-Trinity basin (NRC 2004). Prior to European colonization salmonid runs were likely much larger (650,000-1,000,000 fish annually) than today (Gresh et al. 2000, citing Radke, personal communication).

Dams have been a common feature of the Klamath basin since initial federal funding for hydrologic projects in the early 20th Century. The National Reclamation Act was passed in 1902 and the Klamath Irrigation Project began construction in 1906. The latest project, Keno Dam (OR), was completed in 1967. Approximately 57% of the irrigated agricultural land in the upper basin is provided by the Klamath Irrigation Project (owned by the United States Bureau of Reclamation [USBR]), including 240,000 acres of croplands in southern Oregon and northern California (Chaffin et al. 2015). Dam building and power generation in the region was overseen by the California Oregon Power Company (COPCO). The Copco 1 Dam was the first to be constructed in 1909 and the most recent project in California was construction of Iron Gate Dam in 1962 (Chaffin et al. 2015). COPCO merged with Pacific Power and Light (abbreviated PacifiCorp) in 1961. PacifiCorp's Klamath Hydroelectric Project (FERC No. 2082) currently consists of seven hydroelectric developments: Eastside, 3.2 MW; Westside, 0.6 MW; J.C. Boyle, 98 MW; Copco 1, 20 MW; Copco 2, 27 MW; Fall Creek 6, 2.2 MW; Iron Gate, 18 MW; and one non-generating dam (Keno). The project generates approximately 716 gigawatt-hours of electricity annually, enough to supply 70,000 households. PacifiCorp operates the Link River Dam (owned by USBR) in coordination with the company's other hydroelectric projects. The Link River Dam located upstream of PacifiCorp's projects (Table 6.1, Figure 6.1) controls storage within and releases from Upper Klamath Lake, the largest freshwater lake in Oregon. Keno Dam, located 35.4 km (22 miles) downstream of the Link River Dam, does not produce electricity but regulates the water level in Keno Reservoir/Lake Ewauna as required by the operating license for the project issued by the Federal Energy Regulatory Commission (ESSA 2017).

Table 6.1. Major dams in the Klamath basin including their distance from the Pacific Ocean (river kilometer). J.C. Boyle, Copco 1 and 2, and Iron Gate Dams make up the Klamath Hydroelectric Project (KHP) and currently anticipated to be removed in 2022. Iron Gate Dam is the current upstream limit of anadromy. Rkm = river kilometer; RM = river mile. From: ODFW and the Klamath Tribes 2019, with modification.

Dam	River	State	Rkm	RM	Year completed
Link River Dam	Link River (head of Klamath R.)	Oregon	414.4	257.5	1927
Keno Dam	Klamath River	Oregon	380.5	236.4	1966
J.C. Boyle Dam	Klamath River	Oregon	366.9	228.0	1958
Copco 1 Dam	Klamath River	California	324.9	201.9	1918
Copco 2 Dam	Klamath River	California	324.4	201.6	1925
Iron Gate Dam	Klamath River	California	312	193.9	1962
Dwinnell Dam	Shasta River	California	65	40.4	1928
Trinity Dam	Trinity River	California	193	119.9	1962

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6.2 Habitat Condition

Habitat conditions for all salmonids in the Klamath basin have been affected by numerous anthropogenic factors including urbanization, agriculture, forestry, mining, dams/hydropower, and fishing (Thorsteinson et al. 2011). Habitat fragmentation has negatively affected UKTR spring Chinook Salmon migration, foraging for food, predator avoidance, and productivity. Poor instream habitat condition has also affected their ability complete their life cycle through increased mortality at all life stages (Thorsteinson et al. 2011). Dams in the basin have blocked access to upstream spawning and rearing habitat, creating reservoirs that altered (degraded) temperature and flow conditions, and affected nutrient and sediment transport processes. Land disturbance/conversion and water withdrawals have altered natural flows, increased local thermal loading, reduced natural wood inputs, and increased nutrient inputs and contaminant concentrations (Thorsteinson et al. 2011).

The condition of the remaining accessible habitat in the Klamath basin is a primary factor leading to reduced representation and distribution of the UKTR spring Chinook Salmon ecotype. The primary causes of UKTR Chinook Salmon habitat degradation in the Klamath basin are dams, water management, legacy gold mining, and forestry. Barriers, particularly during low flows, restrict movement and migration. Historical mining operations, logging, and land use conversion cause geomorphic changes, including slope and bank instability and erosion of fine sediment input to the channel, which decreases the quality of spawning habitat and reduces complexity of the low flow channel (NMFS 2014).

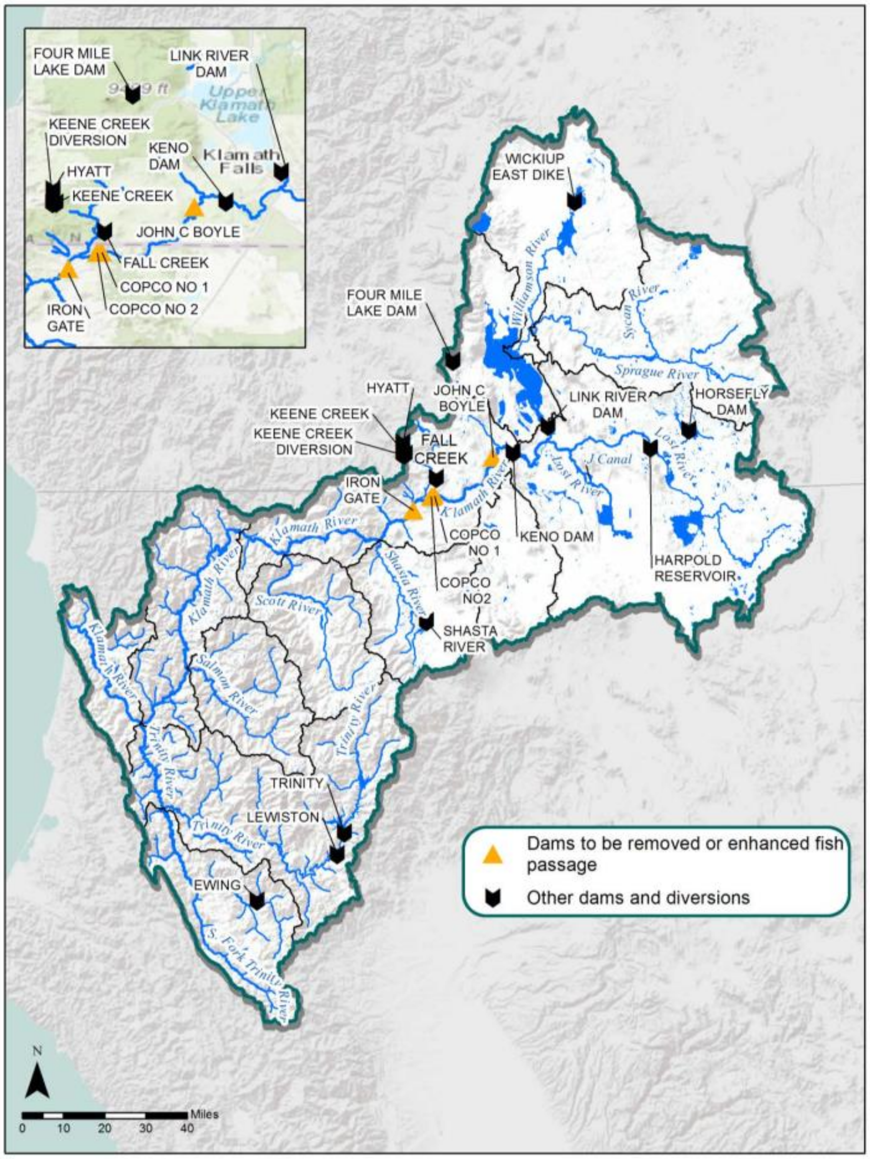

Figure 6.1. Dams and diversions in the Klamath-Trinity basin in California and Oregon. Inset shows four dams currently scheduled for removal. From: ESSA 2017.

Historically, the Klamath River was fed by shallow lakes and marshes that provided cold water inputs during drier periods. Over 80% of these wetlands have been drained, which has led to decreased flows and higher water temperatures (NRC 2004). In the Trinity and Salmon Rivers, land use changes and groundwater pumping have led to a disconnection of surface and groundwater that also results in higher temperatures and lower summer flows (NRWQCB 2005). These decreased flows and high summer water temperatures are exacerbated by loss of riparian cover and reduced structure in the low flow channel (NRWQCB 2005), which further reduces habitat quality for both UKTR spring and fall Chinook Salmon (NRC 2004). The Salmon River is identified as impaired for temperature in accordance with Section 303(d) of the federal Clean Water Act (NRWQCB 2005). Elevated summer water temperatures in the Salmon River limits carrying capacity by restricting adult holding and juvenile rearing of UKTR spring Chinook Salmon to a few thermal refugia (NMFS 2014).

Other Clean Water Act Section 303(d) listings for impaired waters in the basin include:

- Lower Klamath River downstream of the Trinity River for nutrients, organic enrichment/low dissolved oxygen, and temperature;
- Klamath River between the Scott and Trinity rivers for hepatotoxic microcystins from cyanobacteria, nutrients, organic enrichment/low dissolved oxygen, sediment, and temperature;
- South Fork Trinity River for mercury, sedimentation/siltation; and
- East Fork Trinity River for mercury, sedimentation/siltation.

The geology of the Trinity Alps is such that hillslopes are highly susceptible to erosion. Throughout the basin, logging and logging roads have decreased stability of the already steep and unstable slopes. Fine sediment enters the rivers and clogs spaces between gravel, reducing hyporheic flow and salmon egg survival (NRC 2004). Furthermore, deforestation reduces the recharge of aquifers due to faster runoff and less groundwater recharge, which in turn reduces groundwater input to streams during dry months.

In the Salmon River, legacy gold mining has had a profound effect on habitat condition. Hydraulic mining led to considerable channel aggradation, widening and shallowing alluvial reaches, coarsening the bed, reducing habitat complexity, filling of pools, decreasing connection with groundwater, and reducing floodplain connectivity (Stillwater Sciences 2018; NMFS 2014). Placer mining added an estimated 20.3 million cubic yards of sediment to river and eroded over 1,800 acres of riparian and floodplain (Hawthorne 2017; de la Fuente and Haessig 1993, as cited in Stillwater Sciences 2018). These impacts disconnect and/or significantly reduce the amount and quality of spawning, adult holding, and rearing habitat in the Salmon River (NMFS 2014).

The Upper Trinity River was dammed and diverted as part of the Central Valley Project, and the currently accessible portion is highly modified by legacy gold mining and a severely modified flow regime. Beginning in 1964, the USBR began diverting up to 90% of Upper Trinity River flow into the Sacramento River basin, which was followed by a severe decline in UKTR spring Chinook Salmon and other anadromous fishes (NRC 2004). Nearly two decades of fishery studies in the Upper Trinity River informed a flow study (USFWS 1999) that became the basis of a process resulting in formation of the Trinity River Restoration Program (TRRP; USDI 2000). The TRRP's restoration strategy includes managing instream flows, mechanical channel rehabilitation, gravel augmentation, watershed restoration to reduce fine sediment input, improving infrastructure to accommodate floodplain inundation, and an adaptive management program. Channel rehabilitation projects associated with the TRRP—including mechanical alteration of the channel, riparian planting, wood placement, and gravel augmentation—were evaluated in 2014 (Buffington et al. 2014). The review concluded that restoration actions have increased salmon habitat, although not as much as the TRRP targeted, and that management actions had a modest positive effect.

In the South Fork Trinity River, unsustainable grazing and farming has led to loss of riparian habitat, erosion, and geomorphic changes (NRC 2004). These impacts increase stream temperature, decrease habitat quality through loss of complexity and input of large wood, and increase erosion and sedimentation.

Poor water quality and quantity are stressors on both UKTR spring and fall Chinook Salmon in the Klamath River. High temperature and low dissolved oxygen create critically stressful conditions, especially for UKTR spring Chinook Salmon adults and juveniles in the summer months (June through September). Salmon productivity in the Salmon River is limited by high water temperatures that reduce adult holding and summer rearing habitat in the mainstem Salmon River, while increased fine sediment input within the watershed reduces spawning and rearing habitat quality in some locations (Elder et al. 2002).

6.3 Climate Change Projections and Potential Fish Habitat Impacts

The Earth's climate is warming, and the primary causes are greenhouse gas emissions and deforestation (IPCC 2007; USGCRP 2009; USGCRP 2017). A warming climate is likely to result in poorer future environmental conditions for California's salmonids in general, and for UKTR spring Chinook Salmon specifically.

Since 1900 global average temperature has increased 0.7° C (NRC 2006) due to carbon dioxide emissions. Ice core data indicates that atmospheric carbon dioxide is currently 30% greater than its peak in the last 800,000 years. Over the last 150 years, carbon dioxide levels have increased 37.5% (Figure 6.2).

These greenhouse gas increases have resulted in changes in seasonal precipitation, decreased snowpack, earlier snowmelt, and increased storm severity (USGCRP 2009; USGCRP 2017), 0.1° C increase in seas surface temperature since 1961 and increased ocean acidification (USGCRP 2009), 203 mm increase in sea level after approximately 2000 years of stability (USGCRP 2009), and approximately a 20% decrease in the amount of arctic sea ice since the 1950s (Curran et al. 2003).

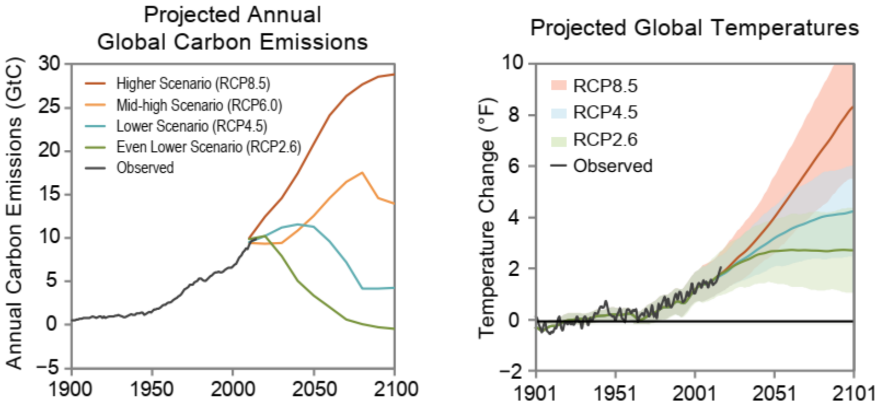

Figure 6.2. Annual historical and range of plausible future carbon emissions (gigatons of carbon per year) and historical and future temperature change for a range of future scenarios relative to the 1901 – 1960 average. Lines show central estimates and shaded areas show 2-standard deviation range as simulated by the CMIP5 global climate models. Projected range of global mean temperature change by 2081 – 2100 for lower to higher carbon reduction scenarios is 1.1 – 4.3 °F (green), 2.4 – 5.9 °F (blue), 3.0 – 6.8 °F (not shown), and 5.0 – 10.2 °F (orange). From: USGCRP 2017.

By the end of this century, atmospheric carbon dioxide concentrations are projected to be two to three times greater than in the last 800,000 years (Figure 6.3). If current conditions remain unchanged, studies project that global climate will change drastically. Projections include an increase of 1.1 – 6.4° C in average global surface temperature (USGCRP 2009), sea level rise of 1 – 3 m (IPCC 2007; USGCRP 2009; USGCRP 2017), and greater extremes in storm events and wildfire (Krawchuck et al. 2009).

UKTR Chinook Salmon are likely to experience worsening environmental conditions in the future as a result of climate change. The UKTR spring Chinook Salmon ecotype may be disproportionately affected because of their life history that includes an early adult return and extended holding period in fresh water. Issak et al. (2018) compiled multidecadal climate data and calculated trends at 391 riverine sites on Northwestern rivers. Recent 20- and 40-year periods saw warming trends in summer and early fall of 0.18 – 0.35° C per decade between 1996 – 2015 and 0.14 – 0.27° C per decade between 1976 – 2015. These changes paralleled air temperature trends and were mediated by local trends in discharge. The authors found that future warming of 1 – 3° C would increase Sockeye Salmon *(O. nerka*) exposure by 5 – 16% and reduce thermally suitable riverine trout habitat by 8-13% causing an upstream shift in distribution. The study found that most salmon and trout rivers in the Northwestern United States will continue to provide habitat for salmonids into the foreseeable future; however, they also concluded that some river reaches will inevitably become too warm to support salmonid habitat.

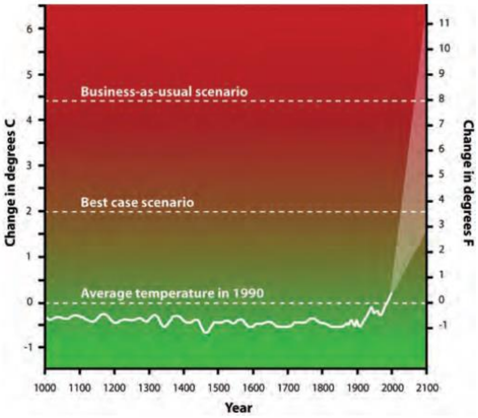

Figure 6.3. Global mean temperature for the last 1,000 years and projected temperatures to 2100. Constant lines show average temperature in 1990, best case scenario if greenhouse gas emissions are drastically cut, and projected temperature if greenhouse gas emissions increase at current rate. From: Barr et al. 2010, adapted from IPCC 2007.

In a modeling study of water temperature specific to the lower mainstem Klamath River, Bartholow (2005) found evidence of increases of 0.5° C per decade (95% CI 0.42 – 0.60° C) since the early 1960s. The period of stressful high temperatures has also increased by one month with average amount of cool water in summer declining approximately 8.2 km (5.1 miles) per decade. Water temperature changes were not associated with water availability but were associated with increases in air temperature and possibly ocean conditions (i.e., Pacific Decadal Oscillation cycle). The author concluded that the warming trends predicted for the Klamath River could negatively impact salmonid recovery in the basin.

Cline et al. (2019) examined the potential effects of climate change and competition on Sockeye Salmon life history. The authors found that warming climate decreased the time spent in the freshwater phase due to enhanced growth at higher temperature. This in turn led to younger age at the time of ocean entry. Early ocean entry in turn caused a potential for increased ocean competition with both hatchery-origin and natural-origin fish that delayed maturity in the ocean. Consequently, fish spent an additional year in the ocean phase prior to return. Smaller size at age also affected the vulnerability to fisheries. Climate warming increasingly favors a shift to a single dominant age class, but simplification of age class complexity degrades resiliency by reducing variation in life-history expression. Although Cline et al.'s (2019) study specifically referenced potential climate change impacts to Sockeye Salmon in Alaska, similar warming scenarios could also be relevant to Chinook Salmon in California, including potential for future declines of the UKTR spring Chinook Salmon life-history type.

The Klamath-Trinity basin is very large resulting in highly variable current climatic conditions from the lower to upper basin (Table 6.2). Temperatures are generally lower in the upper and lower basins and higher in the mid basin region. Precipitation in the upper basin is often snow, whereas in the lower and mid basins precipitation is mostly rain.

Table 6.2. Average temperature and precipitation in the upper, mid, and lower Klamath basin.

Basin	Location	Average annual high/low temp (°F)	January Average high/low temp (°F)	July Average high/Low Temp (°F)	Precipitation (inches)
Upper	Klamath Falls	61/35	38/21	86/51	13.5
Mid	Orleans	71/44	51/35	93/54	51
Lower	Klamath	61/45	54/38	66/52	80

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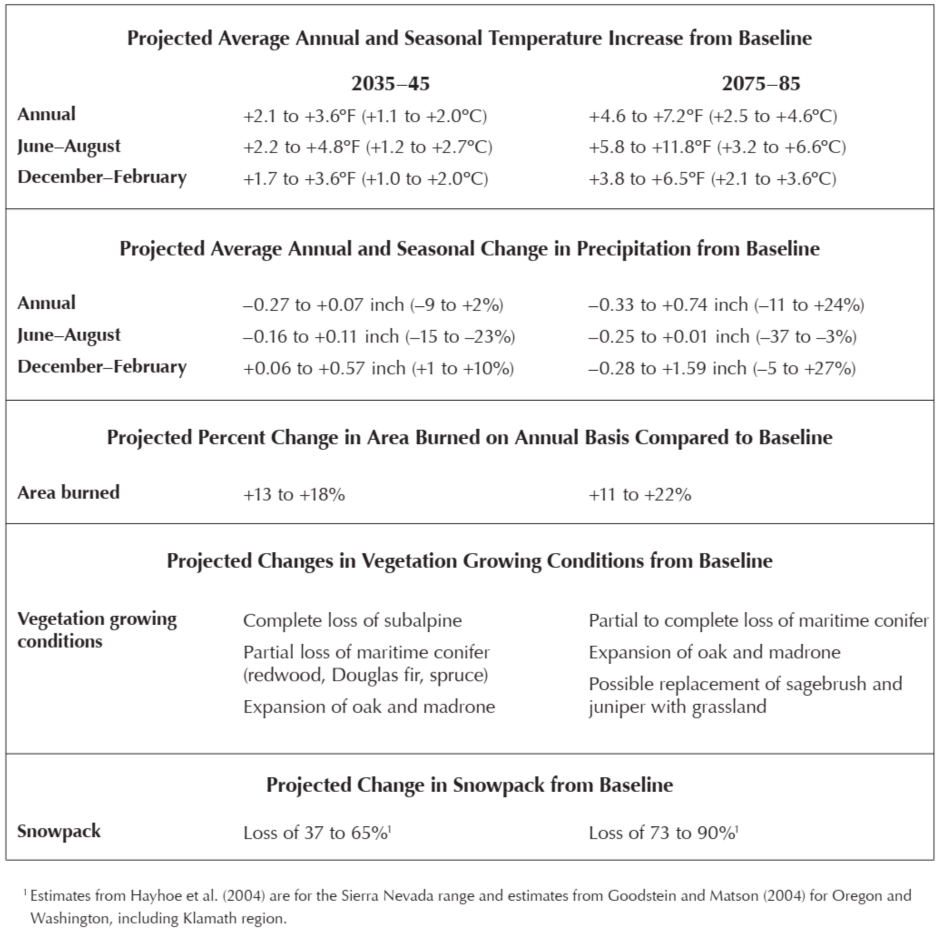
Climate change projections for the Klamath basin are for generally warmer and drier conditions in comparison to those in the past. Barr et al. (2010; Figure 6.4) present results of climate models and a vegetation model for the Klamath basin. Models project annual average temperature increase by about 1.1 – 2.0° C by mid-century, and 2.5 – 4.6° C by late century. Summer warming was projected to be greater than warming in other seasons. Average annual precipitation projections were for a potential range of 11% decrease to 24% increase in rainfall; however, they found that all models showed future summers likely to be 3 – 37% drier than in the past. Vegetation modeling predicted a shift in the upper basin to conditions favoring grasslands in places where climate now supports sagebrush/juniper vegetation type. Conditions in the lower basin favored oak/madrone communities where maritime coniferous forests (coast redwood, Douglas fir, Sitka spruce) now predominate.

Current water quality in the basin is poor in many places and is likely to decline further in the future due to projected increases in water temperature. The Klamath basin is likely to experience warmer water, fluctuating dissolved oxygen levels, and earlier, longer, and more intense algal blooms. More frequent disease outbreaks are also projected due to lower stream flow and increased temperature. Temperature refugia will increase in importance for aquatic species.



	2035–45	2075–85
Projected Average Annual and Seasonal Temperature Increase from Baseline		
Annual	+2.1 to +3.6°F (+1.1 to +2.0°C)	+4.6 to +7.2°F (+2.5 to +4.6°C)
June–August	+2.2 to +4.8°F (+1.2 to +2.7°C)	+5.8 to +11.8°F (+3.2 to +6.6°C)
December–February	+1.7 to +3.6°F (+1.0 to +2.0°C)	+3.8 to +6.5°F (+2.1 to +3.6°C)
Projected Average Annual and Seasonal Change in Precipitation from Baseline		
Annual	–0.27 to +0.07 inch (–9 to +2%)	–0.33 to +0.74 inch (–11 to +24%)
June–August	–0.16 to +0.11 inch (–15 to –23%)	–0.25 to +0.01 inch (–37 to –3%)
December–February	+0.06 to +0.57 inch (+1 to +10%)	–0.28 to +1.59 inch (–5 to +27%)
Projected Percent Change in Area Burned on Annual Basis Compared to Baseline		
Area burned	+13 to +18%	+11 to +22%
Projected Changes in Vegetation Growing Conditions from Baseline		
Vegetation growing conditions	Complete loss of subalpine Partial loss of maritime conifer (redwood, Douglas fir, spruce) Expansion of oak and madrone	Partial to complete loss of maritime conifer Expansion of oak and madrone Possible replacement of sagebrush and juniper with grassland
Projected Change in Snowpack from Baseline		
Snowpack	Loss of 37 to 65%[1]	Loss of 73 to 90%[1]

[1] Estimates from Hayhoe et al. (2004) are for the Sierra Nevada range and estimates from Goodstein and Matson (2004) for Oregon and Washington, including Klamath region.

Figure 6.4. Climate change projections of climate and vegetation models applied to the Klamath basin due to climate change. From: Barr et al. 2010.

More fine sediment is projected due to more frequent and more intense storms and more precipitation occurring as rain. Erosion will likely increase, leading to negative impacts on spawning salmon. Other fish species in the basin (e.g., steelhead, trout, suckers, lamprey) will be likewise affected. Sediments will contain large nutrient loads that will likely further exacerbate algal blooms.

Stream flow is projected to increase in winter and decrease in other seasons because more precipitation will likely be in the form of rain. Frequency of flooding may also increase. Shifting flow patterns and flooding could affect migration timing of adult and juvenile anadromous fish, possibly altering selective regimes that support existing diversity patterns. Because more precipitation is projected to fall as rain in future, snowpack will be reduced, and the melt season will be shorter. This could affect flow patterns and reduce off channel nursery areas. Decreased flows in spring, summer, and fall are likely. Streams that are currently at low flows will likely become intermittent or might cease flowing altogether.

Groundwater flows originating from springs are likely to decline and small springs could dry entirely. Cold water refugia are currently important to anadromous fish in portions of the basin (e.g., Shasta River and other places; Belchik 1997) and are likely to increase in importance with projected changes in climate (Barr et al. 2010).

6.4 Disease

Disease strongly affects anadromous salmonids and other fish in the Klamath River. Principal diseases include ceratomyxosis, columnaris disease, and *Ichthyophthirius multifilis* (“ich”). In some years, these diseases have severely impacted Klamath fish populations causing large die-offs of both juveniles and adults. Seasonal flow management adjustments (e.g., at Trinity River and Link River dams) are used to reduce downstream disease outbreaks when they occur. Disease outbreaks in both the upper and lower basin are triggered and worsened by poor water quality that simultaneously favors disease vectors and stresses fish, making them more susceptible to infection (ESSA 2017).

Several pathogens have been found to contribute to mortality in wild Chinook Salmon in the Klamath River basin. In 2002, a large die-off of adults in the lower Klamath River was attributed to infection with a combination of ich and *Flavobacterium columnare* (columnaris) (USFWS 2003, CDFG 2003). High infection rates of juveniles, with *Ceratonova shasta* and *Parvicapsula minibicornis*, have also been linked to disease and reduced numbers of UKTR Chinook Salmon (Stocking and Bartholomew 2004; Nichols and Foott 2005).

Since 2005, growth of toxic algae behind Copco 1 and Iron Gate dams resulted in posted health warnings against water contact (especially health concerns associated with microcystin toxin) in the two reservoirs and the Lower Klamath River (USDI et al. 2012).

Other pathogens endemic to the Klamath basin that can cause disease in salmonids include bacterial infections caused by *Renibacterium salmoninarum* (the causative agent of bacterial kidney disease, or BKD), *Flavobacterium psychrophilum* (the causative agent of bacterial cold water disease, or CWD), *Aeromonas hydrophila*, and *Yersinia ruckeri* (the causative agent of enteric redmouth disease, or ERM); *Saprolegnia* sp. (external water mold); *Nanophyetus salmincola* (Foott et al. 1997); and various external protozoan (single-celled) and monogenean (flatworm) parasites. Infectious hematopoietic necrosis virus (IHNV) has not been isolated from fish at Trinity River Hatchery since 1999 or from fish at Iron Gate Hatchery since 1997; however, the Department's virology records indicate that it remains common in Sacramento Valley Chinook Salmon runs.

Environmental factors that may contribute to disease include elevated water temperature, low dissolved oxygen, low water flow, elevated pH, and elevated nutrient levels. Toxic cyanobacteria blooms have also been detected in the Klamath River watershed (Fetcho 2006).

Climate change is predicted to negatively influence several of these environmental factors, increasing risk of disease and pathogen effects on the UKTR Chinook Salmon ESU. Therefore, this factor may have a greater effect on survival and reproduction of the ESU in the future.

6.5 Climatic Variation in the Ocean

The California Current Ecosystem (CCE) runs from the southernmost part of California up through the coast of Washington and serves as home to California's salmonid species during the oceanic portion of their life cycle. The CCE can be divided into three sections: the area north of Cape Mendocino is considered the "Northern CCE", the area between Cape Mendocino and Point Conception is the "Central CCE", and south of Point Conception is the "Southern CCE." Fluctuations in key physical and biological variables such as temperature, currents, and forage species can help serve as indicators to the overall health and stability of the CCE as it relates to Pacific salmon. Several basin-scale indices are used to track fluctuations and changes in the CCE to help inform management through illustration of current and historical trends in the marine environment.

Sea surface temperature plays an important role in marine survival of salmon. Cool water periods are generally associated with increased oceanic circulation and upwelling of nutrient-dense water that feeds lower trophic levels. Nutrients move through the food chain supporting populations of plankton and forage species, which in turn provide a food-rich environment for salmon. Conversely, warm water periods are generally associated with reduced upwelling and more nutrient deficient waters that are less supportive of healthy prey species populations.

The Pacific Decadal Oscillation (PDO) is a climate index that reflects long-term fluctuations in sea surface temperatures in the Northeast Pacific. The PDO is classified into either warm water phases or cool water phases that can persist for decades. In the PDO Index from 1925-2018 (Figure 6.5), the shifts between warm and cool water cycles lasted for more than two decades prior to 1998 (Peterson et al. 2018). Long-term cycles have become less stable in recent years, resulting in more frequent fluctuations without long periods of stability in between. Since 1998, warm and cool water cycles have lasted no more than 6 years before switching to an alternate state (Peterson et al. 2018). The shift from decadal cycles to more frequent fluctuations in ocean conditions translates to a less stable environment for salmon during their marine phase. Shorter periods of a healthy marine environment with an abundant food supply may threaten the development of robust salmon populations.

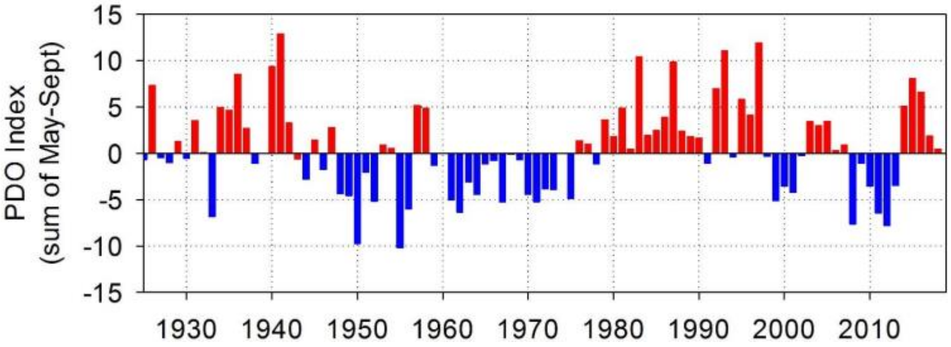


Figure 6.5. Time series of shifts in sign of the Pacific Decadal Oscillation (PDO), 1925 – 2018. Values are summed over the months of May through September. Red bars indicate positive (warm) years; blue bars indicate negative (cool) years. From: Peterson et al. 2018.

The El Niño Southern Oscillation (ENSO) is a periodic fluctuation in wind and sea surface temperatures moving across the equatorial Pacific Ocean that also influences water temperatures in the CCE. The Oceanic Niño Index (ONI) tracks changes in sea surface temperature and reflects fluctuations between El Niño phases characterized by warm water conditions, and La Niña phases characterized by cool water conditions. Strong El Niño events result in the transport of warm equatorial waters northward into the CCE and are generally associated with weaker upwelling, lower primary productivity, and change in community composition of salmon forage species. La Niña conditions are associated with cool water periods and higher productivity. Strong El Niño events were observed in 1972, 1983-84, 1997-98, and more recently in 2015-2016 (Figure 6.6).

The North Pacific Gyre Oscillation (NPGO; Figure 6.7) index tracks changes in sea surface height in the North Pacific. Fluctuations in the NPGO index are indicative of the type of source waters entering the CCE. Positive NPGOs are associated with increased flow from subarctic source waters which bring in higher surface salinities, nutrients, and chlorophyll-*a* to the CCE resulting in stronger circulation, coastal upwelling, and higher productivity at the lower trophic levels. Negative NPGOs are associated with weaker oceanic circulation and lower productivity. Over the last five years, the NPGO has declined to near historic lows indicating a recent trend of weak circulation, low influx of nutrient-rich water, and low primary productivity (NMFS 2019).

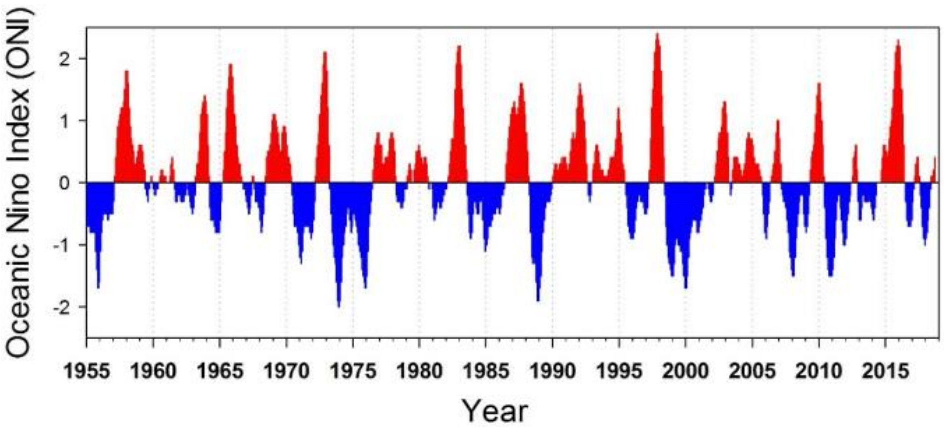


Figure 6.6. Values of the ONI, 1955 – 2018. Red bars indicate warm conditions in the equatorial Pacific, blue bars indicate cool conditions in equatorial waters. From: Peterson et al. 2018.

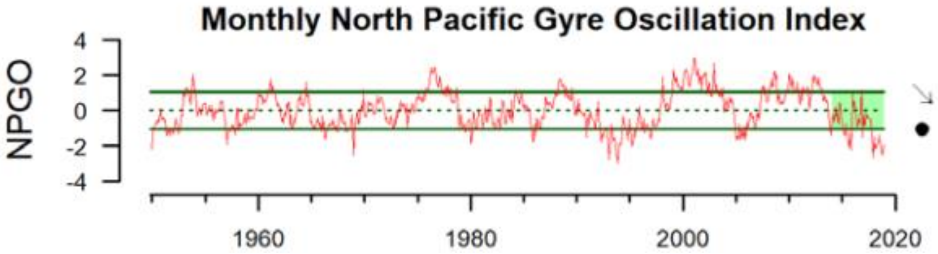


Figure 6.7. Monthly values of the North Pacific Gyre Oscillation (NPGO) from 1950 – 2018. Indicator data relative to the mean (dashed line) and ±1 standard deviation (solid lines) of the full time series. Arrow at the right indicates if the trend over the evaluation period (shaded green) was positive, negative, or neutral. From: NMFS 2019.

Regional climatic conditions also play an important role in ocean temperatures and nutrient content in the waters off the California coast (Figure 6.8). Wind systems near the land-sea interface drive coastal upwelling, where wind stress displaces surface waters and deep, nutrient rich waters move up to replace it. Jacox et al. (2018) developed new indices to estimate coastal upwelling. The Cumulative Upwelling Transport Index (CUTI) estimates the vertical transport of water into and out of the surface layers, and the Biologically Effective Upwelling Transport Index (BEUTI) estimates the nutrient content. Together, these indices track the total volume of water moving into and out of the surface layer as well as the quality of that water in terms of nutrient content, which greatly influences productivity. The timing of peak upwelling varies by latitude. Within the Central CCE around Point Arena (CA), the strongest upwelling and peak nitrate flux generally occurs in May and June. During winter, this same area undergoes downwelling and low nitrate flux due to reversing winds. In 2018, BEUTI and CUTI values were generally average through most of the year with particularly strong periods up upwelling and nitrate flux during the spring.

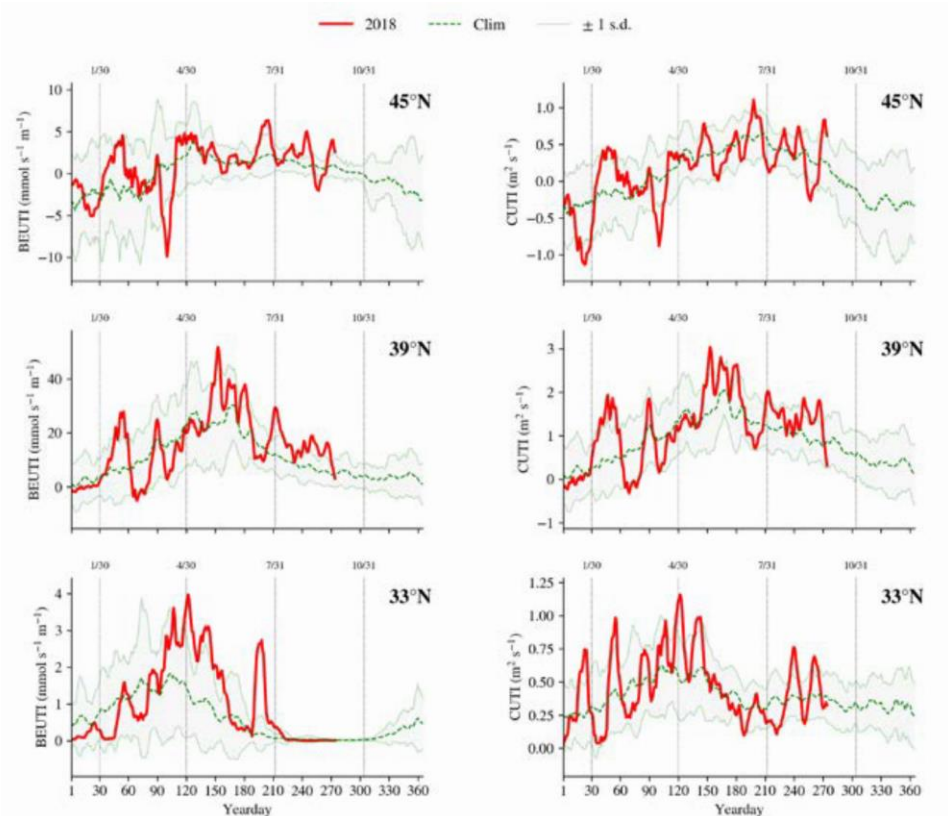


Figure 6.8. Daily 2018 values of Biologically Effective Upwelling Transport Index (BEUTI; left) and Coastal Upwelling Transport Index (CUTI; right) from Jan. 1 – Sept. 1, relative to the 1988 – 2018 climatology average (green dashed line) ±1 standard deviation (shaded area), at latitudes 33° (Southern CA near Point Conception), 39° (Point Arena, CA), and 45°N (Newport, OR). Daily data are smoothed with a 10-day running mean. Vertical lines mark the end of January, April, July, and October. From: Harvey et al. 2019.

Composition and abundance of zooplankton communities are also good indicators of productivity at the lower levels of the trophic system (Figure 6.9). Copepods are an important food source for young Chinook Salmon when they first enter the ocean as well as for many other forage species of fish, such as herring, sardines, and anchovies. However, the nutritional quality of different copepod communities varies greatly depending on their source waters. The CCE is host to several different types of copepod communities: northern copepods – cold-water species rich in fatty acids, and southern copepods – warm-water species with lower fat content and nutritional quality. Southern copepods are more abundant in the CCE during warm-water conditions such as El Niño events and positive PDO regimes, whereas the abundance of lipid-rich northern copepods increases during cool-water conditions such as La Niña years and negative PDO regimes (NMFS 2019). The southern copepod biomass anomaly was particularly strong during the warm water years from 2014 to mid-2017 before moving to a more neutral, and then negative trend by the end of 2018. Within the same time frame, biomass anomalies for northern copepods were negative from 2014 to mid-2017 before moving to more of a neutral value and remaining relatively neutral since. The decline in southern copepods and increase in northern copepods following the recent warm water conditions may signal improved forage conditions for salmon within the northern CCE in recent years (NMFS 2019).

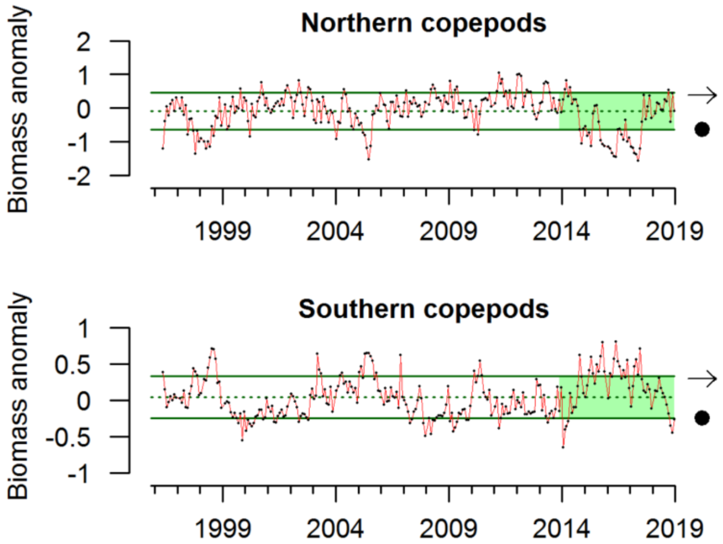


Figure 6.9. Monthly northern and southern copepod biomass anomalies from 1996 – 2018 from transect line off Newport, OR. Indicator data relative to the mean (dashed line) and ±1 standard deviation (solid lines) of the full time series. Arrow at the right indicates if the trend over the evaluation period (shaded green) was positive, negative, or neutral. From: NMFS 2019.

Surveys of the composition and abundance of forage fish species serve as a direct measure of prey abundance for salmon in the CCE. Plots of key forage species in the northern and central CCE over the last 20 years are shown in Figures 6.10 and 6.11. Species are listed on the y-axis and abundance is indicated by color (red signifies abundant and blue signifies rare). Vertical lines indicate a significant shift in regional species composition and horizontal lines indicate clusters of typically co-occurring species. The northern CCE survey of Washington and Oregon saw a dramatic shift in species assemblages beginning in 2014. Between 2006 and 2013, various species of yearling salmon were relatively abundant and market squid were relatively scarce. Beginning in 2014, market squid were consistently abundant and yearling salmon were present only intermittently. In the central CCE, notable changes in species composition started to occur in 2013, as abundance of juvenile sardine, anchovy, market squid, sanddabs, and rockfishes started to climb. Also, worth noting in this cluster analysis is the relative scarcity of adult sardine and herring since 2013, which are common primary prey items for Chinook Salmon in this area; however, adult anchovy, another primary food source for Chinook, were abundant in 2018.

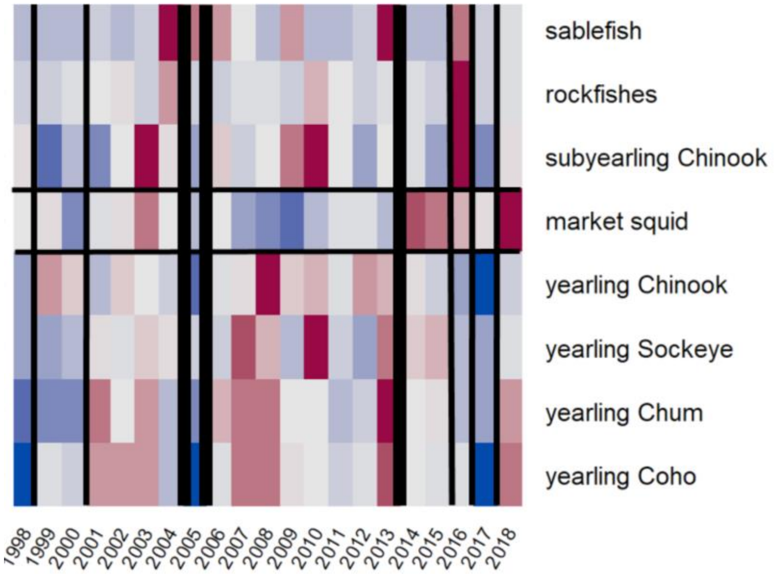


Figure 6.10. Cluster analysis of key forage species in the northern CCE through 2018. Horizontal lines indicate clusters of typically co-occurring species. Vertical lines indicate temporal shifts in community structure. Colors indicate relative abundance (red = abundant, blue = rare). From: NMFS 2019.

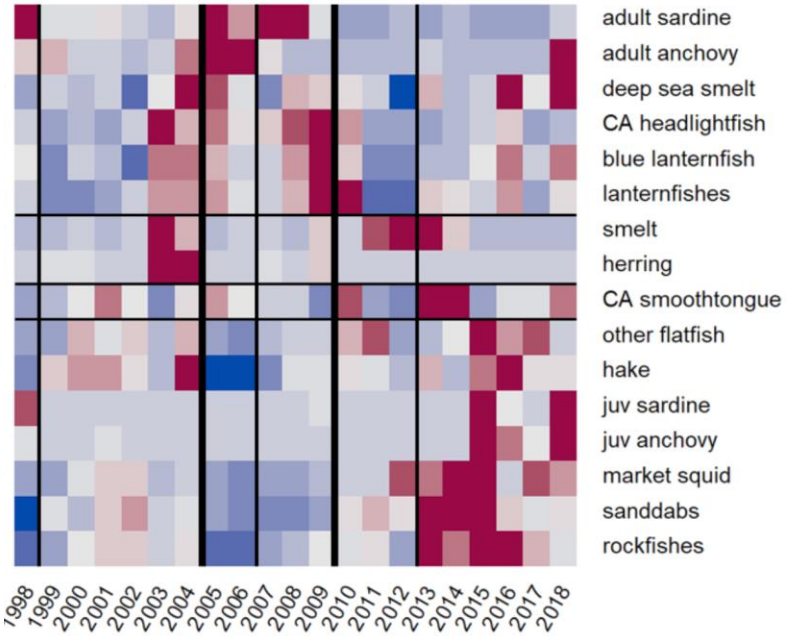


Figure 6.11. Cluster analysis of key forage species in the central CCE through 2018. Horizontal lines indicate clusters of typically co-occurring species. Vertical lines indicate temporal shifts in community structure. Colors indicate relative abundance (red = abundant, blue = rare). From: NMFS 2019.

The marine environment within the CCE has undergone considerable change within the last several years. In addition to the strong El Niño event in 2015-2016 and the positive PDO regime, an unprecedented marine heat wave, popularly known as “The Blob,” appeared off the Pacific coast in 2014-2015. These anomalous and extreme warm water conditions created poor ocean conditions and low prey abundance for salmon, which contributed to historically low adult escapement to both the Klamath and Sacramento river basins in 2017. Fortunately, the above indices indicate a current shift to a more neutral state. However, extremes in ocean conditions are expected to become increasingly common as the effects of climate change are realized.

Ocean acidification, due to increased atmospheric carbon dioxide, is occurring in the world’s oceans, including in the CCE. Sensitivity of salmon to ocean acidification is likely to occur through changes in the food web (Mathis et al. 2015, Busch et al. 2013, Busch et al. 2016), and would be restricted to the marine life-history phase. Abundance of invertebrates such as pteropods, crabs, and krill, which form a large part of the diet of some salmon species, are most likely to be affected by increasing ocean acidity (Wells et al. 2012). Acidification may also act directly on physiological processes affecting olfaction (impairing homing; Munday et al. 2009) and development (Ou et al. 2015). Crozier et al. (2019), using scoring techniques in Morrison et al. (2015) estimated that relative salmon sensitivity is associated with diet. Zooplankton feeders (e.g., Sockeye Salmon, Chum Salmon, Pink Salmon) are more sensitive to ocean acidification than piscivorous species (e.g., Chinook Salmon, Coho Salmon, steelhead). However, populations of Chinook Salmon can also be affected by krill abundance and availability during the period of initial ocean entry (Wells et al. 2012).

6.6 Drought

Drought is a familiar feature of California's climate; however, the most recent 2012-2016 drought was one of the warmest and driest on record, affecting both aquatic and terrestrial environments across the state (Figure 6.12; CDFW 2018a). In response, the Department conducted habitat monitoring for 17 aquatic species/subspecies in 141 watersheds spanning 38 counties throughout the state. Many of the species monitored were state and/or federally listed or California Species of Special Concern. Because of their reliance on cold, clear water for major portions of their life cycle, salmonid fishes were a special focus for monitoring.

Low flow conditions, lasting months during the drought, were expected to be a strong stressor on both juvenile and adult salmonids. Heat stress is known to occur in salmonids at temperatures of 15 – 18° C, with mortality at temperatures above 25°C (Bjornn and Reiser 1991). Low dissolved oxygen levels associated with high temperatures and low flows are lethal for both adults and juveniles below 3.0 mg/L (Matthews and Berg 1997). Due to lack of precipitation, streams that usually flowed all year often went dry in part or entirely during drier portions of the year. Streams experienced earlier drying and compromised habitat conditions (e.g., low dissolved oxygen, low flow, higher temperature). Habitat fragmentation reduced the ability of salmonids and other aquatic species to adapt to poor conditions by moving to better habitat.

Estuaries and lagoons were also impacted by extended drought. Estuaries experienced more pronounced tidal influence due to reduced fresh water inflow. The saltwater bottom layer experienced lower dissolved oxygen levels, likely affecting migrating and rearing juvenile anadromous salmonids. The timing and extent of seasonal river mouth openings deviated from that for non-drought years, affecting timing of anadromous fish migration both into and out of streams.

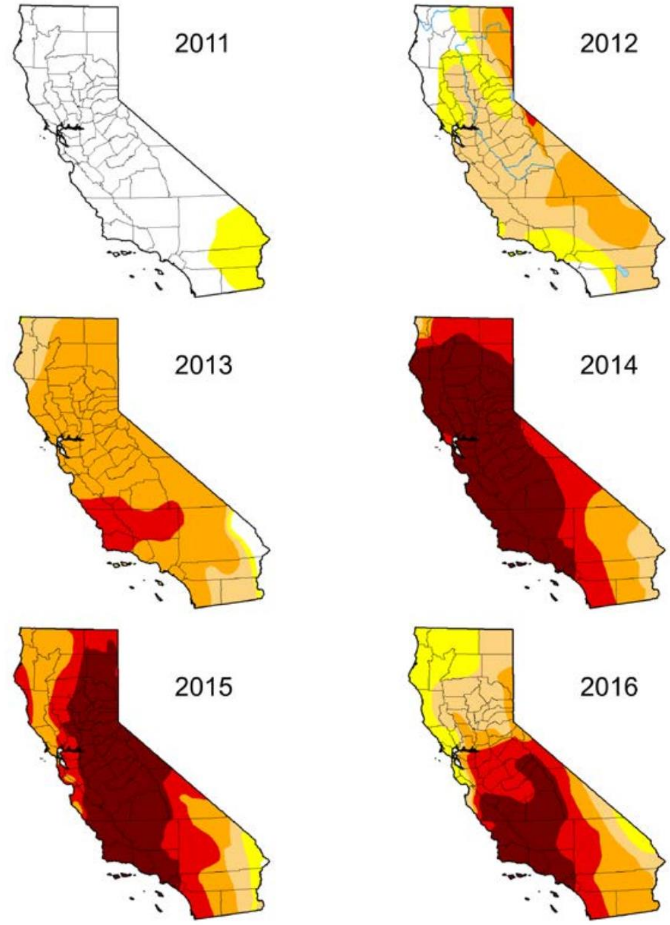


Figure 6.12. The distribution and progression of drought conditions in California from 2011 – 2016, depicting the level of drought at the beginning of each Water Year (October 1). Dark red indicates exceptional drought. From: CDFW 2018a, original map source: U.S. Drought Monitor.

Although the spring ecotype of UKTR Chinook Salmon ESU were not a focal taxa in CDFW (2018a), the overall pattern for coastal anadromous waters was that “higher than normal water temperatures associated with the drought exceeded survival thresholds and probably affected the spawning success and survival of salmon and steelhead in coastal watersheds” (CDFW 2018a). In addition, low flows during the drought period in the Shasta River led to high water temperatures in summer months. Baseflows at the confluence of the Klamath and Shasta rivers were less than 5 cubic feet per second (cfs)—the lowest flows on record. During most of the summer months, maximum daily water temperatures were above 18°C.

Although drought monitoring data specific to effects on the spring ecotype of UKTR Chinook Salmon ESU is scarce, the Department concludes that the recent drought likely had a negative effect on extant populations. Drought conditions may have been a major stressor leading to recent declines observed in both UKTR spring and fall Chinook Salmon.

6.7 Hatcheries

Two anadromous salmonid hatcheries produce UKTR Chinook Salmon in the Klamath-Trinity watershed. Trinity River Hatchery (TRH; on the Trinity River at Lewiston Dam) has had active UKTR spring Chinook Salmon and UKTR fall Chinook Salmon programs since construction of the hatchery in 1964. Iron Gate Hatchery (IGH; on the Klamath River at Iron Gate Dam) was constructed in 1966. IGH historically also produced both UKTR spring and fall Chinook, but currently only produces UKTR fall Chinook Salmon. The Chinook Salmon programs at both hatcheries are considered primarily mitigation to compensate for lost production due to habitat loss above dams.

The following subsections discuss the status, trend, and potential impacts of IGH and TRH hatchery programs on natural and listed fish, the California Hatchery Scientific Review Group performance review, specific program elements at IGH and TRH relevant to status and trend, potential results of dam removal on the Klamath River, and reintroduction plans for UKTR spring Chinook Salmon that potentially involve use of hatchery fish.

6.7.1 Potential Impacts of Hatchery-Origin Fish on Natural-Origin and ESA-Listed Fish

For over a century, hatcheries along the Pacific Coast have produced hundreds of millions of hatchery salmon. Largely these fish have been produced in support of fisheries, although some recent hatchery programs have a conservation focus. Although the number of hatchery fish in the Pacific Ocean is great, natural-origin populations continue to decline.

Anadromous salmonid hatcheries have been a feature of the Klamath basin since the construction of large dams on the Klamath and Trinity rivers blocked access to much of those rivers’ anadromous fish spawning and rearing habitat. Both in-river and ocean fisheries are strongly supported by annual releases of large numbers of hatchery Chinook Salmon in this region (see below). Over the entire Pacific Northwest, numerous studies have concluded that hatchery practices, along with large harvests that hatcheries support, have contributed to declines of natural spawning populations of anadromous salmonids (e.g., Waples 1991b, 1999; Lichatowich 1999; Levin et al. 2001; Naish et al. 2007).

Hatcheries have the potential to both increase annual numbers of propagated stocks and negatively impact their long-term prospects for natural area persistence. Impacts can be genetic, ecological, and behavioral (for reviews see CDFG 2002; Naish et al. 2007; Flagg et al. 2000). Competition, predation, straying, stock introgression, masking of declines, reduced fitness, and inbreeding and outbreeding depression have been documented in many studies in many anadromous salmonid species (Naish et al. 2007). Reviews of the potential and realized impacts of hatchery-origin fish on natural stocks can be found in Naish et al. (2007), Flagg et al. (2000), CDFG (2002), among many others. Because of the persistent declines observed in Pacific salmon, including collapse of West Coast salmon fisheries in 2008 (Lindley et al. 2009), the United States Congress authorized recent efforts to improve Pacific salmon hatchery programs in Washington, Oregon, and California (HSRG 2015; CA HSRG 2012).

6.7.2 Introgression of UKTR Spring and Fall Chinook Salmon at Trinity River Hatchery

It is generally assumed that UKTR spring and fall Chinook Salmon were once more reproductively isolated than they are today (see Range and Distribution). The construction of Lewiston Dam on the Trinity River in 1964 resulted in truncation of the total Chinook Salmon spawning habitat, resulting in potential for increased spring and fall interbreeding on the Trinity River. Prior to dam construction on the Trinity River, UKTR spring Chinook Salmon were thought to spawn farther upstream early in the fall, with UKTR fall Chinook Salmon spawning downstream later in the fall (Kinziger et al. 2008b). Artificial propagation of both UKTR Chinook Salmon ecotypes at TRH further increased the chances of unintentional introgression of the spring and fall ecotypes.

Kinziger et al. (2008b) reported on a genetic survey of Chinook Salmon broodstock at TRH during the 1992 return year. They found that the proportion of UKTR spring and fall Chinook Salmon in returning adults shifted over the spawning season, with a higher proportion of UKTR spring Chinook Salmon early in the season and a higher proportion of UKTR fall Chinook Salmon later. Simulation studies showed there is potential for spring-fall hybridization, especially in the middle of the spawning season. The study could not determine whether similar hybridization had been occurring prior to dam construction and hatchery production.

6.7.3 California Hatchery Scientific Review Group Recommendations

Beginning in the year 2000, the United States Congress embarked on a hatchery review process to maintain the social and commercial benefits of anadromous fish hatcheries while protecting natural and listed salmon and steelhead populations. The first review was conducted for Puget Sound and Coastal Washington hatchery programs (2004) and was later expanded to hatcheries in the Columbia River basin (2005). In 2010, Congress authorized and funded a review of most of California’s salmon and steelhead hatchery programs. A group of hatchery experts, the

California Hatchery Scientific Review Group (CA HSRG), was created to conduct the review. Their work over an 18-month period resulted in the CA HSRG review document published in 2012 (CA HSRG 2012).

The goal of the CA HSRG hatchery review was to provide guidance to manage and operate hatchery programs to help recover and conserve listed and naturally spawning salmon and steelhead populations and support sustainable fisheries with little or no deleterious consequence to listed and natural populations. The programs at both IGH and TRH were included in this review.

The CA HSRG developed recommendations for improvement of all hatchery programs at both Trinity River and Iron Gate hatcheries and specific recommendations applied to individual programs with the goal of reducing negative impacts of these hatchery programs. These recommendations can be found in *Appendix A* of this report. Some, but not all, of the recommendations have been implemented.

6.7.4 Iron Gate Hatchery

Iron Gate Hatchery currently produces UKTR fall Chinook Salmon and also conducts a conservation hatchery program for Coho Salmon. It does not currently produce UKTR spring Chinook Salmon, although it did at one time. Prior to 1995-96, IGH also had a robust steelhead program. However, that program produced very few fish in the last decade due to low broodstock returns and was recently terminated.

UKTR fall Chinook Salmon produced at IGH are adipose fin-clipped and coded wire tagged (CWTed) at a constant annual rate of 25% following the Department's standard. UKTR fall Chinook Salmon production at IGH, along with TRH UKTR spring and fall Chinook Salmon production, form the base stock for in-river and ocean fisheries in the region. The ocean abundance of age-4 IGH UKTR fall Chinook Salmon is also used as a surrogate for management of the ESA threatened California coastal Chinook Salmon ESU (O'Farrell et al. 2015).

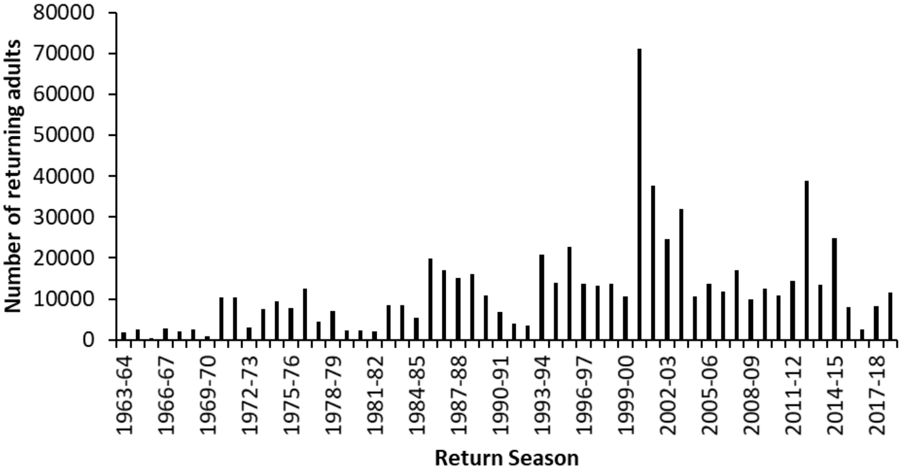


Figure 6.13. Annual total adult UKTR fall Chinook Salmon returns to Iron Gate Hatchery 1963 – 2019.

Annual returns of UKTR fall Chinook Salmon to IGH consistently numbered in the thousands to the tens of thousands throughout the monitoring period (Figure 6.13). The numbers of fish returning since 1985-86 appear to be generally greater than in earlier years. The lowest recent return occurred in the 2016-17 season during which only about 3,000,000 eggs were taken. Current season (2019-20) returns to the hatchery were also relatively low for this program (approximately 4,000 adults; Patrick Brock, CDFW, Personal Communication, November 2019). The most recent notably large season was 2001-02 with more than 71,000 UKTR fall Chinook Salmon returning to the hatchery.

Some UKTR spring Chinook Salmon (generally less than 100 per year; Table 6.3) returned to IGH between 1968 and 1979. Returns were inconsistent and low during this period with decreasing numbers of adults observed over time. The hatchery suspended trapping the following year and between 1979-2001 because spring Chinook Salmon were not observed returning in late- spring or summer. No UKTR spring Chinook Salmon have been recorded trapped at IGH, either early or late in the return season, between 2001 and the present (Table 6.3; Patrick Brock, CDFW, personal communication, November 2019).

Table 6.3. Fall-trapped and spring-trapped UKTR spring Chinook Salmon returning to Iron Gate Hatchery, 1962-2019

	Fall-trapping[1]		**Spring-trapping**	
Season	**Adult**	**Grilse**	**Adult**	**Grilse**
1962-63 through 1967-68	Data Not Available			
1968-69	NA	NA	50	6
1969-70	8	3	51	0
1970-71	2	0	10	0
1971-72	16	0	80	0
1972-73	97	4	49	0
1973-74	18	5	4	0
1974-75	19	8	0	0
1975-76	25	28	0	0
1976-77	13	0	0	0
1977-78	0	0	0	0
1978-79	17	0	0	0
1979-80 through 2000-01	No trapping due to lack of spring Chinook Salmon in late-spring and summer			
2001-2019	No spring Chinook Salmon trapped either early or late			

[1] Fall-trapped UKTR spring Chinook Salmon are the same brood year as the spring-trapped UKTR spring Chinook Salmon of the preceding reporting period. UKTR spring Chinook Salmon were not differentiated from UKTR fall Chinook Salmon prior to 1968-69.

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6.7.4.1 Trends in UKTR fall Chinook Salmon Returns to IGH

Both long-term (1963 – 2019) and recent (12-years, 2008-2019) trends in returns to IGH were calculated. Methods were the same as those used to assess trends in natural abundance in *Section 4 Status and Trend*, of this document. Trend greater than one indicates an increase, and trend less than one indicates a decrease, in returns over the time period analyzed. The long-term trend in returns to IGH was 1.036, with 95% confidence intervals of 1.022 – 1.050. Recent trend (12-years or 4-generations) for returns to the hatchery was 0.939, with 95% confidence intervals of 0.831 – 1.062. Although the long-term trend in returns is clearly positive, the recent return trend is slightly negative suggesting that average numbers of UKTR fall Chinook Salmon returning to the hatchery may have declined over the period 2008 – 2019. However, the Department cannot conclude that a decline occurred with certainty because the confidence intervals range from below one (decline) to above one (increase).

6.7.4.2 Annual Production of UKTR fall Chinook Salmon at IGH

Annual IGH hatchery-origin Chinook Salmon inputs to the basin have been large. Between 1988 and the present, IGH released an average of 4,958,957 UKTR fall Chinook Salmon smolts and 948,468 yearlings annually (Table 6.4). Recent (10-year) average releases are 3,750,668 smolts and 982,281 yearlings. Recent annual production has been relatively stable at high release numbers. However, long term trend in UKTR fall Chinook Salmon smolt production has slightly declined over the period (high certainty; data not shown) and yearling production slightly increased (but with high uncertainty; data not shown). The notably low production of fall ecotype fingerlings in the 2017 release year was due to very low take of eggs, prompting the Department's decision to prioritize the yearling program to increase fishery contributions and returns to the hatchery (Wade Sinnen and Patrick Brock, CDFW, Personal Communication, November 2019).

6.7.4.3 Impacts of Dam Removal on IGH Hatchery Operations

Iron Gate Dam, along with three other upstream dams, are slated for removal starting in 2022 if permits are received on schedule (see *Section 7 Klamath Dam Removal*). In the process, IGH, in its current form, will become non-functional due to lack of water to the facility. Current plans contemplate modifications at IGH to continue producing fish; however, at the time of this review, plans for continued Klamath River hatchery production have not been finalized. The most recent proposal is for some fall Chinook Salmon production and all Coho Salmon production to be moved upstream to a small facility on Fall Creek (see Figure 7.1 for details) just prior to and for at least eight years post dam removal. All steelhead production, which has been very minimal in recent years, will cease at IGH. New construction and refurbishment of the Fall Creek Hatchery facility is planned. At this time, it is unknown what actual production will be at the hatcheries; however, total UKTR fall Chinook Salmon production at the smaller facility will most likely be less than current production.

6.7.5 Trinity River Hatchery

Trinity River Hatchery (TRH) was constructed in 1964 as part of the Trinity River Division of the Central Valley Project to mitigate for the loss of anadromous fish habitat above Lewiston Dam. TRH is located at rkm 177 (rm 110) near the town of Lewiston in Trinity County, California. The facility is owned by the USBR and operated by the Department. The hatchery originally produced UKTR spring and fall Chinook Salmon, Coho Salmon, steelhead, and brown trout. TRH currently produces UKTR spring Chinook Salmon, UKTR fall Chinook Salmon, steelhead, and Coho Salmon.

Table 6.4. Annual production of UKTR fall Chinook Salmon smolts and yearlings at IGH. Yearling releases typically occur in October – November and smolt releases in May – June. Data from: Patrick Brock, CDFW, November 2019.

Release year	Brood Year	Number of Smolts	Number of Yearlings	Total Releases
1988	1987	11,360,000	1,129,240	12,489,240
1989	1988	10,186,000	992,023	11,178,023
1990	1989	5,100,000	0	5,100,000
1991	1990	5,402,659	1,000,000	6,402,659
1992	1991	3,570,000	1,099,071	4,669,071
1993	1992	3,300,312	1,155,096	4,455,408
1994	1993	4,962,344	982,562	5,944,906
1995	1994	4,913,457	904,107	5,817,564
1996	1995	5,626,408	407,177	6,033,585
1997	1996	5,286,641	1,088,280	6,374,921
1998	1997	5,103,476	1,096,436	6,199,912
1999	1998	4,965,229	1,122,127	6,087,356
2000	1999	5,028,070	1,055,112	6,083,182
2001	2000	4,938,000	1,092,636	6,030,636
2002[1]	2001	4,966,640	1,087,081	6,053,721
2003	2002	5,116,165	1,083,900	6,200,065
2004[2]	2003	5,182,092	685,819	5,867,911
2005	2004	5,370,342	842,848	6,213,190
2006	2005	6,171,838	874,917	7,046,755
2007	2006	5,363,972	984,502	6,348,474
2008	2007	5,290,005	1,105,870	6,395,875
2009	2008	3,976,305	773,165	4,749,470
2010	2009	4,528,056	852,129	5,380,185
2011	2010	3,937,878	944,369	4,882,247
2012	2011	4,640,814	1,148,932	5,789,746
2013	2012	3,361,672	979,668	4,341,340
2014	2013	4,427,279	993,717	5,420,996
2015	2014	3,826,185	943,489	4,769,674
2016	2015	3,644,648	966,712	4,611,360
2017	2016	411,872	1,016,779	1,428,651
2018	2017	4,174,040	994,737	5,168,777
2019	2018	4,554,239		
average		**4,958,957**	**948,468**	**5,920,481**
10-year average	**3,750,668**	**982,281**	**4,643,664**	

[1] 2002-2019 Fish released in groups as size threshold reached or when river temp. reached 65 °F

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[2] 2004-2019 Fall Creek rearing pond facility not used

Mitigation goals for TRH, intended to mitigate for fish habitat losses due to dam construction, were established based on pre-project anadromous fish population studies. Studies by USFWS/CDFG (1956) estimated that 3,000 UKTR spring Chinook Salmon and 8,000 UKTR fall Chinook Salmon spawning fish historically passed above Lewiston Dam. Annual adult production goals were established in 1980 to meet return targets (escapement plus catch) of 6,000 UKTR spring Chinook Salmon, and 70,000 UKTR fall Chinook Salmon. Current production goals for TRH UKTR Chinook Salmon are shown in Table 6.5. At the direction of NMFS, the UKTR spring Chinook Salmon smolt release window was changed from 1 – 15 June to 15 – 31 May to minimize the total number of UKTR spring and fall Chinook Salmon hatchery-origin fish released to the river at any one time, reducing competition with hatchery fish (D. Muir, CDFW, Personal Communication, November 2019).

TRH broodstock originated from collections at a weir in the Trinity River starting in 1964. The program has not used out of basin sources of eggs or broodstock for at least the last 10 years.

Table 6.5. Annual Trinity River Hatchery UKTR spring and fall Chinook Salmon production goals.

Ecotype	Green eggs	Release Type	Prod. goal	Min. size	Fecund.	Females	F:M	Release date
Spring	3,000,000	Smolts	1,000,000	90/lb	2,500	1,200	1:1	15-31 May
		Yearlings	400,000	10/lb				1-15 Oct
Fall	6,000,000	Smolts	2,000,000	90/lb	2,750	2,182	1:1	1-15 Jun
		Yearlings	900,00	10/lb				1-15 Oct

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6.7.5.1 Broodstock History and Spawning

Currently TRH UKTR spring Chinook Salmon broodstock are collected at the hatchery's fish ladder and gathering tank (fish trap), directly below Lewiston Dam. Adults are held in-river for up to four months (June – September) until the adult trap is opened just after Labor Day. To avoid mixing spring and fall broodstock, the fish trap is closed for approximately 14 days between return seasons: approximately between 12 – 25 October of each year. UKTR fall Chinook Salmon spawning commences about the last week in October. Hatchery staff initially separate spring and fall fish by appearance. Overlap of hatchery-origin spring and fall Chinook Salmon is also monitored by reading CWTs of fish used for spawning. If necessary, egg lots with mixed spring-fall parentage are culled prior to eye-up to maintain separation of ecotypes in the hatchery. Overlap of fall and spring Chinook Salmon occurs on both sides of the spawning break. After the 14-day closure, the trap is opened to begin collection of fall Chinook Salmon broodstock. Fall broodstock are separated from spring spawning fish by appearance.

Commented [SN100]: I encourage genetic testing of markers from greb1L/rock1 to verify the expected transition

Annual female broodstock targets are 2,182 UKTR fall Chinook Salmon females and 1,200 UKTR spring Chinook Salmon females. UKTR fall Chinook Salmon produce an average of 2,750 eggs/female, and UKTR spring Chinooks Salmon average 2,500 eggs/female. Spawning occurs two days per week for both spring and fall ecotypes. Fall Chinook Salmon may be spawned on a third day to make use of previously unripe females. The current spawning protocol is to sequentially pool gametes of four females with five males[10]. An average of 1,146 females are spawned each year to allow for culling and to meet production goals. Broodstock are mostly age-3 with some age-2 fish, rarely age-4. Table 6.6 shows the number of broodstock spawned each year.

Using proportions of CWT recoveries, hatchery staff estimate the proportion of natural-origin broodstock (pNOB) is about 0.1 (10%). All releases are volitional[11], and directly from the hatchery to the Trinity River. Annual production of Chinook Salmon at TRH is shown in Table 6.6.

6.7.5.2 Rearing, Marking/Tagging, and Release

Approximately 1.4 million UKTR spring Chinook Salmon fry are grown annually. Fish for both smolt and yearling releases are initially grouped together. For both UKTR spring and fall Chinook Salmon, there is a smolt (55 fish per pound; fpp) release 1 – 15 June, and a yearling (10 fpp) release 1 – 15 October. Both UKTR spring and fall Chinook Salmon hatchery fish are adipose fin-clipped (marked) and CWTs are applied at a rate of 25% according to the Department standard. A portion of the UKTR spring Chinook Salmon production, about 50,000 fish, are released unmarked to calibrate screw traps near Willow Creek. The yearling group, approximately 440,000 fish, is segregated from the general population prior to release. Originally, yearlings were selected from the earliest and latest egg takes. However, current practice is to select the yearling group from pooled juveniles representing all pairings throughout each run.

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[10] This spawning technique is known to reduce the number of males contributing to production because of sperm competition. The true proportion of males to females spawned, in terms of offspring contribution, is less than reported.

[11] Volitional release is a juvenile hatchery release practice that allows fish to leave the hatchery by choice, rather than being forced out of the hatchery at a given time. It results in more protracted emigration as fish naturally become ready to migrate to the ocean.

6.7.5.3 TRH UKTR spring and fall Chinook Returns

Both UKTR spring and fall Chinook Salmon returns to TRH are generally in the thousands, with some years exceeding ten thousand annually (Figure 6.14). Table 6.6 shows annual numbers of both UKTR spring and fall Chinook Salmon since the beginning of program operation at TRH. Figure 6.15 shows the pattern of recent annual returns of UKTR Spring Chinook Salmon from 2002 – 2003 through the present.

Return trend for the TRH spring and fall Chinook Salmon programs was calculated as in *Section 4 Status and Trend*. The long-term spring Chinook Salmon return trend between 1971 – 2019 was 1.005, with 95% confidence intervals of 0.990 – 1.021. The more recent 12-year trend (2008 – 2019) was 0.928, with 95% confidence intervals of 0.857 – 1.004. Production of spring Chinook Salmon at TRH, although variable, has shown no clear pattern of increase or decrease over either monitoring period.

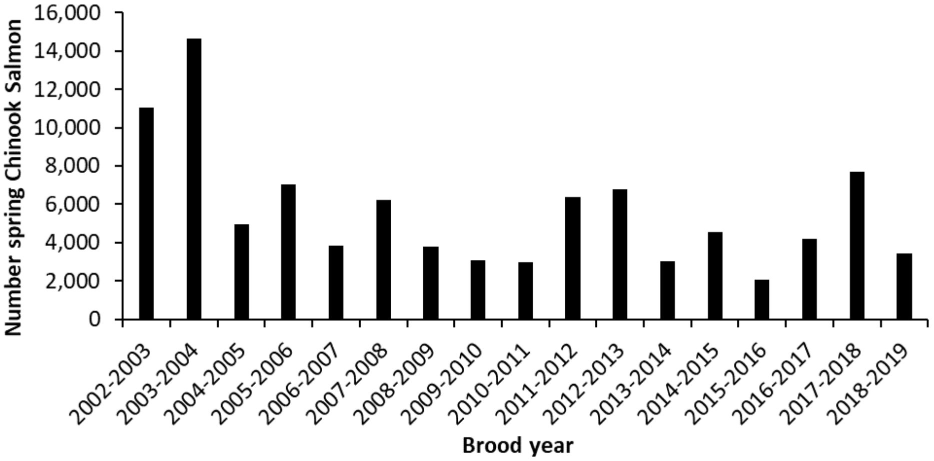

Figure 6.14. Number of UKTR spring Chinook Salmon trapped annually at Trinity River Hatchery

UKTR fall Chinook Salmon returns to TRH are variable but large, with thousands to tens of thousands of fish arriving annually (Table 6.6). Long-term (1971 – 2019) return trends for fall Chinook Salmon to TRH is 1.019, with 95% confidence intervals of 1.004 – 1.035, indicating a statistically supported slight increase in returns over the monitoring period. The 12-year trend however shows a slightly negative trend, but without statistical support. Overall, trend in fall Chinook Salmon returns to the hatchery appear to be about the same or slightly increasing.

Although a clear pattern of decline in TRH returns is not apparent in the above analysis, Sullivan and Hileman (2019), using different methods, found evidence that all age classes of marked and unmarked Chinook Salmon returning to TRH have declined in relative abundance since 2003.

Table 6.6. Annual UKTR spring and fall Chinook Salmon production at Trinity River Hatchery, 1958-59 through 2018-19 seasons. From: CDFW, TRH Annual Reports.

	UKTR spring Chinook Salmon				UKTR fall Chinook Salmon				
Season	**Trapped**	**Females Spawned**	**Fingerlings Released**	**Yearlings Released**	**Trapped**	**Females Spawned**	**Fingerlings Released**	**Yearlings Released**	**Notes:**
1958-59									1st year of operation Lewiston Trapping Station - fish moved above dam site while dam under construction.
1959-60									
1960-61	556				6,910	494	993,900		Females spawned collected Oct 1960. Fingerlings released were actually swim-up fry.
1961-62	284				5,113	831	2,427,070		284 spring Chinook Salmon trucked back to river downstream of dam site. Females spawned collected Oct 1961. Fingerlings

	UKTR spring Chinook Salmon				**UKTR fall Chinook Salmon**				
Season	**Trapped**	**Females Spawned**	**Fingerlings Released**	**Yearlings Released**	**Trapped**	**Females Spawned**	**Fingerlings Released**	**Yearlings Released**	**Notes:**
									released were actually swim-up fry.
1962-63					9,451		1,848,400		TRH operations begin 15 May 1963. "A few" spring Chinook Salmon were observed. Fingerlings released were actually swim-up fry.
1963-64			80,000		6,735	2,409	4,624,900		First spawn at TRH. Spring fingerlings are "assumed spring" from early spawns. Females spawned includes fall and assumed spring ecotypes.

	UKTR spring Chinook Salmon				UKTR fall Chinook Salmon				
Season	Trapped	Females Spawned	Fingerlings Released	Yearlings Released	Trapped	Females Spawned	Fingerlings Released	Yearlings Released	Notes:
1964-65			100,000		6,303	2,869	7,341,300	300,000	Spring fingerlings are "assumed spring" from early spawns. Females spawned includes fall and assumed spring ecotypes. 300,000 yearlings were in bad condition.
1965-66					3,075	930	1,300,000	224,548	Females spawned includes fall and assumed spring ecotypes. Fingerling mortality was high due to gas bubble disease.
1966-67					2,054	1,000	2,873,600	0	Females spawned includes fall and assumed spring ecotypes.
1967-68					2,870	1,164	3,758,050	52,185	Females spawned includes fall and

	UKTR spring Chinook Salmon				UKTR fall Chinook Salmon				
Season	Trapped	Females Spawned	Fingerlings Released	Yearlings Released	Trapped	Females Spawned	Fingerlings Released	Yearlings Released	Notes:
									assumed spring ecotypes.
1968-69					3,899	1,897	4,252,000	518,400	Females spawned includes fall and assumed spring ecotypes. Spring and fall not counted separately. Fingerlings said to be "mostly fall." Yearlings not separated by fall/spring.
1969-70	109	19	0	500,000	2,477	762	1,270,230	0	Hatchery records start to include some level of separation of spring and fall returns and production.
1970-71	1,847	231	0	*	2,597	455	1,665,494	75,000	Fall yearlings here are actually

	UKTR spring Chinook Salmon				UKTR fall Chinook Salmon				
Season	**Trapped**	**Females Spawned**	**Fingerlings Released**	**Yearlings Released**	**Trapped**	**Females Spawned**	**Fingerlings Released**	**Yearlings Released**	**Notes:**
									probably both spring and fall
1971-72	6,324	2,192	3,922,690	330,373	2,897	1,338	382,030	0	
1972-73	7,791	2,185	3,896,450	256,840	3,590	1,271	937,940	1,045,189	
1973-74	3,104	507	798,376	221,375	2,108	395	0	724,879	
1974-75	4,481	1,248	1,602,425	267,210	3,583	921	664,650	463,565	
1975-76	4,065	1,564	1,535,000	279,995	3,158	1,372	2,557,000	329,073	
1976-77	4,284	1,090	1,902,150	364,210	3,340	377	1,343,925	659,500	
1977-78	1,509	228	0	58,000	4,212	697	390,400	228,100	Fall yearlings are from Klamath R. egg transfer
1978-79	3,899	1,171	*	100,000	7,293	3,025	4,413,883	492,137	Fall fingerlings are combined spring and fall
1979-80	1,544	484	416,900	400,886	2,526	639	409,632	786,857	
1980-81	1,288	137	0	123,728	5,970	1,639	1,481,045	712,450	
1981-82	2,648	839	1,249,475	35,128	3,226	1,239	979,300	971,873	
1982-83	1,549	545	151,875	358,268	6,120	921	430,930	1,093,613	
1983-84	1,135	313	0	332,292	5,788	2,536	2,575,335	860,813	
1984-85	1,273	305	0	434,475	2,471	721	510,000	1,165,781	
1985-86	23,902	2,553	5,352,235	1,713,568	11,786	2,984	210,250	901,913	Hatchery records begin to clearly separate spring and

	UKTR spring Chinook Salmon				**UKTR fall Chinook Salmon**				
Season	**Trapped**	**Females Spawned**	**Fingerlings Released**	**Yearlings Released**	**Trapped**	**Females Spawned**	**Fingerlings Released**	**Yearlings Released**	**Notes:**
									fall returns and production.
1986-87	5,669	1,478	2,092,770	492,860	22,278	5,322	3,680,881	1,018,440	
1987-88	10,839	1,159	2,803,226	486,048	15,401	2,601	2,350,205	982,784	
1988-89	15,880	1,228	1,938,914	0	20,506	2,210	2,921,982	93,300	
1989-90	6,663	953	1,725,237	608,580	9,709	1,604	2,749,774	1,112,412	
1990-91	2,676	1,207	1,839,541	348,914	1,580	663	0	1,099,574	
1991-92	862	251	210,188	600,262	2,510	709	581,539	643,910	
1992-93	2,116	456	488,219	375,301	3,683	1,585	2,342,037	933,796	
1993-94	2,951	1,395	1,498,015	485,260	1,273	217	202,275	972,074	
1994-95	3,196	974	1,458,984	800,205	7,292	1,415	2,153,982	213,563	
1995-96	9,317	1,763	1,057,037	474,980	14,925	2,459	2,038,461	950,015	
1996-97	4,984	1,388	1,034,825	405,480	6,147	2,198	2,101,306	910,500	
1997-98	5,147	777	1,294,518	414,579	6,250	1,403	2,403,407	916,971	
1998-99	4,787	1,425	1,148,984	420,511	14,626	3,347	2,050,636	907,354	
1999-2000	4,222	1,657	959,019	399,134	7,169	2,049	1,991,693	993,382	
2000-01	12,192	1,000	1,093,525	390,506	27,028	1,983	2,113,804	863,267	
2001-02	6,955	1,005	1,032,548	401,743	18,200	1,809	2,084,069	872,666	
2002-03	11,063	1,192	1,005,179	425,701	4,500	1,331	2,078,192	940,049	
2003-04	14,646	1,127	1,060,735	443,686	30,509	1,996	2,103,459	908,913	
2004-05	6,563	963	724,081	436,615	13,389	2,067	2,065,329	956,688	
2005-06	7,049	1,223	1,100,718	431,380	13,380	2,988	2,099,237	965,356	

	UKTR spring Chinook Salmon				**UKTR fall Chinook Salmon**				
Season	**Trapped**	**Females Spawned**	**Fingerlings Released**	**Yearlings Released**	**Trapped**	**Females Spawned**	**Fingerlings Released**	**Yearlings Released**	**Notes:**
2006-07	3,833	1,118	947,501	417,165	12,241	2,502	2,021,056	965,516	
2007-08	6,036	1,376	737,929	390,136	18,114	2,474	1,065,605	1,001,176	
2008-09	3,786	1,242	940,937	424,823	5,235	2,026	2,018,580	980,211	
2009-10	3,092	1,199	662,156	442,953	7,559	2,241	1,975,162	927,141	
2010-11	2,956	1,022	733,351	412,147	8,951	1,843	1,936,149	954,382	
2011-12	6,364	927	756,709	444,873	16,346	1,897	1,836,464	858,821	
2012-13	6,801	1,303	1,045,003	364,640	17,471	2,093	1,687,329	982,968	
2013-14	3,035	1,144	631,583	365,787	3,965	1,544	2,118,989	988,247	
2014-15	4,530	907	967,060	436,101	6,225	1,378	1,370,831	987,100	
2015-16	2,076	824	1,000,028	101,905	3,376	1,384	1,964,041	436,674	Data for 2016-19 releases are from planting receipts from Darrick Muir, Nov 2019.
2016-17	2,104	899	1,102,711	438,256	1,557	534	0	1,028,336	Data from Darrick Muir, Nov 2019.
2017-18	1,393	645	869,305	437,909	5,613	1,923	1,983,000	1,015,946	Data from Darrick Muir, Nov 2019.
2018-19	3,449	937	823,505	395,206	7,952	2,198	2,136,438	989,713	Data from Darrick Muir, Nov 2019.
Average	**4,977**	**1,036**	**1,133,169**	**401,837**	**8,043**	**1,670**	**1,896,054**	**745,039**	
Goals			**1,000,000**	**400,000**			**2,000,000**	**900,000**	

6.7.5.4 Trinity River Hatchery Annual Production

Artificial propagation associated with TRH has been active since before the hatchery was built (Table 6.6). Current annual production goals (Table 6.5) for spring are 1,000,000 smolts and 400,000 yearlings, and for fall are 2,000,000 smolts and 900,000 yearlings. Hatchery records only clearly discriminate spring from fall production starting in the 1985 – 1986 season.

Both UKTR spring and fall Chinook Salmon releases from TRH are large. Annual releases from this hatchery are a substantial portion of the total UKTR spring Chinook Salmon productivity for the basin.

Table 6.7. Trends in UKTR spring and fall Chinook Salmon releases from Trinity River Hatchery. Note different time range for fall and spring fish. Data from CDFW, TRH Annual Reports.

	Fingerling Release Trend	Upper 95% CI	Lower 95% CI	Yearling Release Trend	Upper 95% CI	Lower 95% CI
UKTR fall Chinook Salmon 1965-2019	0.993	0.931	1.059	1.095	1.037	1.156
UKTR spring Chinook Salmon 1986-2019	0.997	0.958	0.996	1.038	0.944	1.14

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6.7.5.5 Trends in UKTR spring and fall Chinook Hatchery Production

Data from the Department's Annual Reports were used to calculate trends in annual fingerling and yearling releases of UKTR spring and fall Chinook Salmon from TRH (Table 6.7). Fingerling release trend for both hatchery-origin UKTR spring and fall Chinook Salmon has declined over time and yearling releases have increased in size; however, the changes are small and not all significant. Only UKTR fall Chinook Salmon yearling release increases and UKTR spring Chinook Salmon fingerling decreases are statistically supported. In general, production has been remarkably stable for both release types and for both ecotypes from TRH for several decades.

6.7.5.6 Trinity River Hatchery Spring and Fall Chinook Hatchery Influence

Fall Chinook Salmon hatchery production at TRH is large, whereas spring production is more modest. Additionally, both UKTR spring and fall Chinook Salmon hatchery influence is complicated by production of both smolts, with a lower early life-history survival rate, and yearlings, with a greater survival rate.

Hatchery influence from both hatcheries in the region appears to be most concentrated in the areas adjacent to the hatcheries (Table 6.8; CA HSRG 2012). Spawning survey information (observations of adipose fin-clipped fish) and genetic analyses indicate relatively low hatchery influence in areas farther from IGH and TRH. This is likely due in large part to the policy of releasing both UKTR spring and fall Chinook Salmon hatchery-origin fish at or near the hatcheries (CA HSRG 2012).

Table 6.8. Estimated proportion of hatchery-origin spawning fish (pHOS) for UKTR spring Chinook Salmon natural-area spawning fish in the Upper Trinity River above Junction City Weir and fish trapped at Trinity River Hatchery, 2002 – 2018.

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Year	pHOS natural area spawning fish	pHOS at TRH
2002	0.57	0.93
2003	0.62	0.90
2004	0.59	0.92
2005	0.66	0.89
2006	0.18	0.81
2007	0.79	0.86
2008	0.28	0.83
2009	0.28	0.87
2010	0.26	0.87
2011	0.24	0.95
2012	0.53	0.88
2013	0.58	0.95
2014	0.45	0.89
2015	0.59	0.84
2016	0.12	0.95
2017	0.42	0.98
2018	0.62	0.88
Average	**0.46**	**0.89**
Min	**0.12**	**0.81**
Max	**0.79**	**0.98**

Proportionate Natural Influence (PNI) is a commonly used indicator of hatchery influence (e.g. CA HSRG 2012). A PNI of at least 0.5 ensures that the natural environment rather than the hatchery environment, is the main selective feature shaping adaptations. PNI considers the relationship of the proportion of natural-origin fish used as broodstock and the proportion of hatchery-origin fish that spawn in natural areas:

$$PNI = \frac{pNOB}{pNOB + pHOS}$$

Where *pNOB* is the proportion of natural-origin fish used as broodstock and *pHOS* is the proportion of hatchery-origin fish that spawn naturally. PNI uses numbers of hatchery and natural fish to estimate the effect of hatchery fish on natural stocks. A more advanced version of PNI, called effective *PNI* ($PNI_{effective,}$ HSRG 2015), uses the actual reproductive success of hatchery and natural fish to estimate hatchery impact. Because hatchery fish often have lower reproductive success than natural-origin fish (HSRG 2015), the original PNI calculation is thought to overestimate hatchery influence.

Annual returns of hatchery-origin UKTR spring Chinook Salmon to natural spawning areas have varied greatly (Figure 6.15). Rough PNI calculations support the hypothesis that hatchery influence is greater at the hatchery than in more distant natural spawning locations. In the years 2002-2018, pHOS on the natural UKTR spring Chinook Salmon spawning grounds above Junction City Weir ranged from 0.12-0.79, with an average of 0.46. In contrast, pHOS at the hatchery itself (TRH) was much higher, ranging from 0.81-0.98, with an average of 0.89.

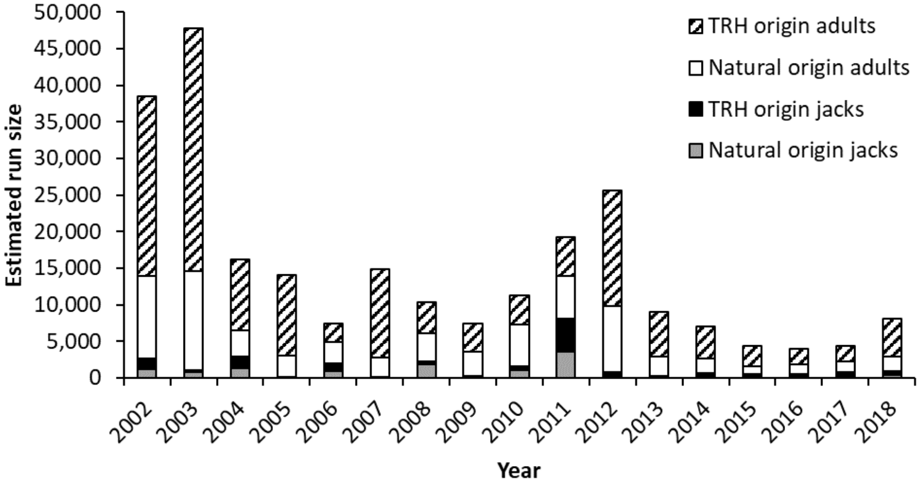

Figure 6.15. Estimated UKTR spring Chinook Salmon run-size for the Trinity River upstream of Junction City weir, 2002 – 2017, showing natural- and TRH-origin composition. Redrawn from: CDFW 2019.

Using the pHOS calculations for the UKTR spring Chinook Salmon natural spawning area above Junction City Weir and at TRH yielded a rough PNI of 0.19 for the Upper Trinity River UKTR spring Chinook Salmon population component. The target PNI for most integrated programs is ≥0.5. For most conservation programs the PNI target is higher (≥0.67) to provide additional protection for recovering populations. The Upper Trinity River UKTR spring Chinook Salmon PNI is considerably short of either target; however, concentration of hatchery fish spawning near TRH is an expected, and even desired, consequence of on-site releases. Such concentration allows for efficient broodstock collection and provides a potential mechanism for removing excess hatchery fish from the system.

Proportion of hatchery-origin fish on spawning grounds for the places where the Department has data (Tables 6.8, 6.9) show that pHOS for both spring and fall Chinook Salmon is approximately 0.5, which just meets a common target to ensure that the natural environment, not the hatchery, is the main driver of evolution in the system (CA HSRG 2012); however, for Spring Chinook, in some years, pHOS is quite high, on the order 60-70%. This indicates that, although average pHOS for UKTR spring Chinook Salmon in the Upper Trinity River is reasonable over the long term, PNI in natural spawning areas near TRH is likely not protective, and that in some years hatchery influence there can be high (Figure 6.15 and Table 6.8).

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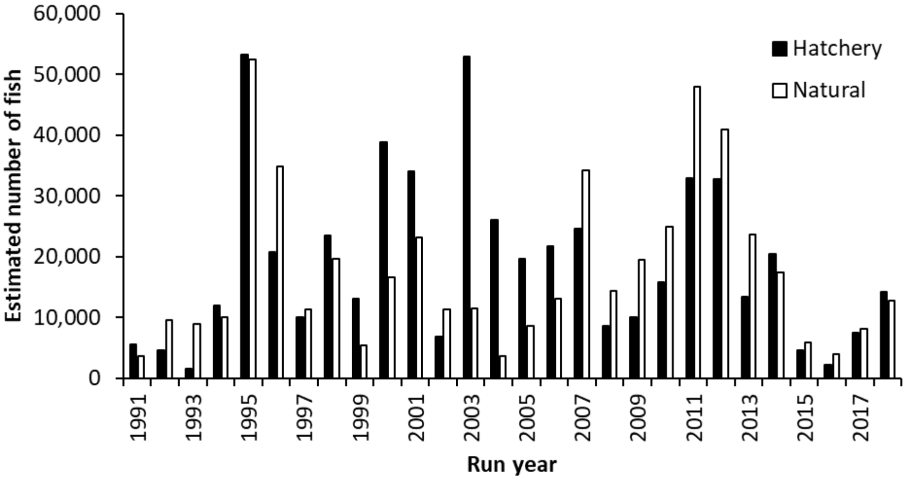

Figure 6.16. Numbers of hatchery and natural UKTR fall Chinook Salmon returns to the Trinity River above Willow Creek Weir 1991 – 2017. Redrawn from: CDFW 2019.

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PNI estimates are not available for all areas where UKTR spring Chinook Salmon spawn. Because returning hatchery fish are concentrated near the hatchery, spring pHOS for distant locations (e.g., the Salmon River) is likely to be much lower, and PNI much higher than for the

Upper Trinity River. Because the area over which pHOS is estimated is important to accurately assess hatchery influence, better and more complete pHOS estimates in all spring Chinook Salmon spawning aggregations are needed.

Table 6.9. Estimated contribution of Trinity River Hatchery-origin UKTR fall Chinook Salmon to the total estimated run size upstream of Willow Creek Weir, 1991 – 2010. Data from: CDFW 2019.

Year	Run size	TRH component	Natural component	% TRH composition
1991	9,207	5,597	3,610	60.80%
1992	14,164	4,651	9,513	32.80%
1993	10,485	1,499	8,986	14.30%
1994	21,924	11,880	10,044	54.20%
1995	105,725	53,263	52,462	50.40%
1996	55,646	20,824	34,822	37.40%
1997	21,347	9,977	11,370	46.70%
1998	43,189	23,536	19,653	54.50%
1999	18,516	13,081	5,435	70.60%
2000	55,473	38,881	16,592	70.10%
2001	57,109	33,984	23,125	59.50%
2002	18,156	6,884	11,272	37.90%
2003	64,362	52,944	11,418	82.30%
2004	29,534	25,956	3,578	87.90%
2005	28,231	19,674	8,557	69.70%
2006	34,912	21,768	13,144	62.40%
2007	58,873	24,633	34,240	41.80%
2008	22,997	8,585	14,412	37.30%
2009	29,593	10,072	19,521	34.00%
2010	40,792	15,853	24,939	38.90%
2011	80,818	32,875	47,943	40.70%
2012	73,666	32,735	40,931	44.40%
2013	36,989	13,371	23,618	36.10%
2014	37,829	20,463	17,366	54.10%
2015	10,365	4,531	5,834	43.70%
2016	6,196	2,188	4,008	35.30%
2017	15,450	7,393	8,057	47.90%
2018	26,848	14,111	12,737	52.60%
Average:	**36,728**	**18,972**	**17,757**	**49.90%**

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6.7.6 Historically Active Small-Scale Hatcheries in the Klamath Basin

Several small-scale hatchery facilities have produced UKTR fall Chinook Salmon in the Klamath basin. None of these produced large numbers of Chinook Salmon but are included here for completeness.

Historical small-scale facilities included:

- Lower Klamath/Hunter Creek: A small facility operated between 1986 – 94 by the Yurok Tribe on the lower Klamath River. The project produced roughly 6,000 – 30,000 Chinook Salmon annually (Lara 1996, as cited in PWA 1994). Average output of the hatchery was 14,850 Chinook Salmon juveniles reared to yearling size. Broodstock were captured for several years near the mouth of Blue Creek using a gill net. Early incubation and rearing were conducted at satellite facilities, transitioning later to a single facility on Spruce Creek. Juvenile releases were mostly in Hunter Creek in the latter years of the program.
- Camp Creek/Red Cap Creek: The Karuk Tribe and the Northern California Indian Development Council (NCIDC) in cooperation with Six Rivers National Forest and the California Department of Fish and Game (Wildlife) operated a small-scale hatchery on Camp Creek near Orleans. The facility began operation in 1986 using native fall Chinook Salmon broodstock. Juveniles are released as yearlings in October. Releases were marked with maxillary clips in early years and with CWTs since 1992. The number of fish released ranged from 4,637 in 1990 to 34,976 in 1995. The total number of juvenile yearling Chinook released by the program from 1986 to 1996 was 173,323 or an average of 17,332 per year.
- Horse Linto Creek (Not within the UKTR Chinook Salmon ESU; however, released fish to the basin): This was a cooperative rearing facility [CDFG, USFS and the Pacific Coast Federation of Fishermen's Association (PCFFA)]. Operations are documented in Hillemeier and Farro (1995). The Horse Linto rearing facility has discontinued operation.

6.7.7 Inter-Basin Transfers and Stray Rates

Inter-basin transfers can result in changes in population structure and blur patterns of between population diversity. Both IGH and TRH have largely used naturally returning Chinook Salmon to the hatchery as broodstock and have released their production directly to the river at or near the hatchery.

In 1973, more than 900,000 UKTR spring Chinook Salmon juveniles from TRH were out planted in the South Fork Trinity River at Forest Glen. This effort was intended to improve returns to the South Fork Trinity after the 1964 flood. Although juvenile release locations were far from the hatchery, this translocation still represents within-basin movement (Kier and Associates 1999).

Kinziger et al. (2008a) reviewed 3,614 Klamath basin hatchery records from 1943-94. Most inter-basin transfers were less than 5,000 individuals; however, some transfers were larger. Table 6.10 shows the large transfers that would be expected to have the greatest impact on genetic structure and diversity of the receiving stock. Although transfers can influence genetic structure and between population diversity, it is unknown how these specific transfers affected those traits.

Some juvenile releases involved translocation from the Upper basin to the estuary. Kinziger et al. (2008a) noted that this practice could increase straying and potentially reduce between population genetic diversity.

Table 6.10. Large inter-basin transfers in the Klamath-Trinity basin. TRH is Trinity River Hatchery. IGH is Iron Gate Hatchery. TRH+IGH indicate mixed stocks of unknown proportions. From: Kinziger et al. 2008a Table 1, with modification.

Hatchery Source	Year	Run	Propagation Location	Release location	Number released
TRH and IGH	1971-77	Fall	TRH	Trinity River	1,891,594
TRH and IGH	1973	Fall	TRH	South Fork Trinity River	930,900
IGH	1975, 83, 85, 86	Fall	IGH	South Fork Salmon River	100,726
TRH	1976	Fall	TRH	Klamath River (Klamath Glen, near estuary)	819,000
IGH	1975-77, 1983-85	Fall	IGH	Klamath River (Klamath Glen, near estuary)	7,143,348

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As noted in a previous section, hatchery influence on natural stocks is concentrated in natural spawning areas adjacent to IGH and TRH. Low hatchery influence in major portions of the Klamath-Trinity in places distant from hatcheries is indicated by few observations of hatchery-origin (i.e., adipose fin-clipped) fish on spawning grounds. Rupert et al. (2017) found that natural-origin Chinook Salmon spawn throughout the mainstem Trinity River whereas hatchery origin fish spawn almost entirely within the two reaches below Lewiston Dam. Genetic analyses (Williams et al. 2013; Kinziger et al. 2008a) also suggest that hatchery fish introgression with natural stocks is generally low.

CWT returns in the South Fork Trinity River from 1985 – 1995 found evidence of straying of fish from some of the small-scale hatchery rearing facilities (Table 6.11; PWA 1994). Strays were from Horse Linto Creek, Hoopa Lower Trinity River project, and Lower Klamath Rearing Project. Stray estimates using these small numbers ranged from relatively low (about 4%) to relatively high (close to 30%). Fish from some of these projects also returned to IGH. The Camp Creek Project did not show evidence of straying within the basin. These small-scale hatcheries are no longer producing fish, so they are not current factors affecting UKTR Chinook Salmon.

Table 6.11. Stray rates of hatchery UKTR fall Chinook Salmon into the South Fork Trinity River basin (1984 – 1990). Small scale hatcheries include Hoopa Fisheries, Horse Linto Creek, and Cappell Creek Hatchery.

				Origin			
Year	**No. fish**	**No. strays**	**total % strays**	**% Unknown**	**% TRH**	**% IGH**	**% Small scale hatcheries**
1984	73	21	28.8	24.7	4.1	0.0	0.0
1985	176	42	23.8	0.0	11.3	11.4	1.1
1986	264	10	3.8	0.0	3.4	0.4	0.0
1987	455	95	21.0	0.0	18.3	0.3	2.4
1988	368	55	15.0	0.0	4.9	0.0	10.1
1989	52	5	9.6	0.0	0.0	0.0	9.6
1990	223	9	4.0	0.0	0.0	0.0	4.0

6.8 Genetic Diversity

As described in *Section 4.5.6 Diversity*, maintenance of within and between population genetic diversity in natural stocks is important to the overall protection of a species. UKTR spring Chinook Salmon exist as an ecotype of the combined UKTR Chinook ESU. As such they are an important diversity element that was once more widely distributed and more abundant than currently. UKTR spring Chinook Salmon spawning aggregations are currently concentrated in the Upper Trinity River, the Salmon River, and the South Fork Trinity River, with scattered very small numbers in smaller tributaries of both the Klamath and Trinity rivers. Of the three larger escapement groups, the South Fork Trinity and Salmon River groups exist as small (10s-100s), fragmented runs (see *Section 4 Status and Trend*). The Upper Trinity River UKTR spring Chinook Salmon run is, by contrast, much larger (1000s). Small population size in the Salmon and South Fork Trinity groups, and overall fragmentation of spawning aggregations of the spring ecotype, is of concern from the standpoint of diversity loss; however, the ESU as a whole exists in large numbers throughout the basin.

6.9 Predation

Predation is not thought to be a primary factor in the decline of UKTR spring or fall Chinook Salmon and does not likely considerably affect the ability of either ecotype to survive and reproduce. Predators of juvenile Chinook Salmon include avian species (e.g., cormorants, gulls, terns, mergansers, egrets, herons, and osprey), native fish (e.g., sculpin, steelhead) and introduced species (e.g., catfish, shad, black bass). Brown Trout (*Salmo trutta*) are the most important non-native predator in the Trinity River. Large marine mammals [e.g., Pacific harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), and killer whales (*Orcinus orca*)] are known to prey on adult salmon. Predation is a natural phenomenon that can be increased to unsustainable levels by human activities such as hard in-river structures (e.g., diversions, bridge abutments, docks, riprap banks), changes in water management that lead to warmer water temperatures, introduction of non-native predator species, and habitat modification.

Warmer water temperatures, loss of habitat complexity associated with riparian vegetation and in-channel wood, and other habitat degradation may have increased predation on juvenile UKTR spring Chinook Salmon as compared to historical levels. However, the Department does not know of any comprehensive studies assessing the relative importance of this threat to UKTR spring Chinook Salmon (NRC 2004). The effects of predation are thought to be minor compared to other impacts, as there are few non-native predator species of UKTR Chinook Salmon in the basin. It has been suggested that hatchery released salmon may prey on natural salmon (e.g., ISAB 2005, as cited in Karuk Tribe and Salmon River Restoration Council 2018). However, the Department does not know of any targeted studies evaluating whether this is a significant effect in the Klamath basin.

Salmon in the Klamath basin evolved with pinniped predators such as California sea lions and Pacific harbor seals, and predation by pinnipeds is not thought to be a major factor in the decline of UKTR spring Chinook Salmon. However, pinniped populations along the California coast are currently large in relation to historic numbers (Laake et al. 2018), and a large population of pinnipeds feeding on salmonids may have a disproportionate effect on small, depressed salmon runs (NMFS 1997). In a 1997 Report to Congress, NMFS (1997) reported that pinniped predation is a potential concern for UKTR spring Chinook Salmon, but that more studies are needed to quantify the level of impact. A 1997-1998 assessment of pinniped predation (Hillemeier 1999, Williamson and Hillemeier 2001) found that some adult UKTR spring Chinook Salmon returning to the estuary were consumed by California sea lions, harbor seals, and Stellar sea lions (*Eumetopias jubatus*). Based on CWT recoveries, several hundred UKTR spring Chinook Salmon from TRH were consumed each year of the study. Although the studies were not designed to specifically evaluate impacts on UKTR spring Chinook Salmon, genetic analyses of scat samples of Pacific harbor seals in the spring of 1998 suggested that salmonids (genus *Oncorhynchus)* make up a small but perhaps significant percentage of the seals' diet, more in the spring than in the fall (Williamson and Hillemeier 2001). CDFW monitored salmonid predation by harbor seals in the lower Klamath River during seining and tagging of adult salmonids between 1984 and 1988, finding that the percentage of seined fish taken by seals ranged from 3.1-5.5% and was relatively constant from year to year (Stanley and Shaffer 1995). This percentage was similar to the expanded salmonid mortality calculated by Williamson and Hillemeier (2001) of approximately 2%. While the results of these evaluations do not specifically quantify the effects of pinniped predation on UKTR spring Chinook Salmon, they suggest that while it may be an added stressor, pinniped predation alone does not considerably affect the ability of the UKTR Chinook Salmon ESU to survive and reproduce.

6.10 Competition

Demonstrating competition is difficult because it requires that one or more resources be limiting, and evidence that competition for those resources produce a niche shift in one or both species (Hearn 1987). Native salmonids, including Rainbow Trout (steelhead), Chinook and Coho salmon, in the Klamath basin evolved and have persisted together for many thousands of years. Salmonids employ variation in reproductive and emergence timing and spatial segregation to avoid and minimize interspecific competition.

Large annual releases of hatchery-origin UKTR fall Chinook Salmon and more modest numbers of UKTR spring Chinook Salmon from IGH and TRH may result in in-river intraspecific competition with natural-origin UKTR Chinook Salmon in the basin, especially for space and thermal refugia (NMFS 2010); however, specific competitive interactions and their effects on natural-origin survival and reproduction are not known.

Non-native salmonids such as Brook Trout (*Salvelinus fontinalis*) and Brown Trout are known to compete and often displace native Redband Trout (*O. mykiss ssp.*) and Bull Trout (*S. confluentus*) from basin streams. These species, as well as other native salmonids (e.g., Rainbow Trout, Coho Salmon) may, to some small extent, compete with UKTR Chinook Salmon when times and areas overlap. However, the effects of these and many of the other invasive species in the basin are uncertain, as little quantitative information exists to evaluate their possible impacts (ESSA 2017).

6.11 Fishing

Klamath River fall Chinook Salmon are managed for a conservation floor escapement target of 40,700 natural area adults annually. The overall harvest rate is determined by the Pacific Fishery Management Council (PFMC), with NMFS guidance, on an annual basis resulting in impact rates to the stock that are designed to achieve the conservation escapement target. Ocean fisheries are structured by season (time and area) and in-river fisheries by quotas to target the overall impact rate cap. In-river harvest, both recreational and tribal are governed by quotas determined by the PMFC that target in-river escapement objectives. Tribal quotas tend to be higher than in-river sport quotas because most of the non-tribal allocation is apportioned to ocean fisheries.

6.11.1 Commercial Fishery Harvest Indices by Stock and Time-Area

The commercial ocean salmon fishery harvests the majority of both UKTR Spring Chinook Salmon produced by the Trinity River Hatchery, and UKTR fall Chinook Salmon which are included in the larger Klamath River Fall Chinook (KRFC) stock[12]. The spring ecotype generally experiences lower harvest indices compared to the fall ecotype (Figure 6.17), similar to the trend seen in the recreational fishery (Figure 6.18). Unsurprisingly, most harvest of both stocks occurs around the stocks' origin in the Klamath Management Zone and Fort Bragg; however, the Central Oregon (Florence, OR, to Humbug Mountain) Management Zone has the highest TRH UKTR spring Chinook Salmon harvest index, driven primarily by a relatively higher harvest index in September. Management areas farther from the Klamath-Trinity basin exhibit lower harvest indices of both stocks (e.g., Cape Falcon to Florence, OR, and the area south of Point Arena).

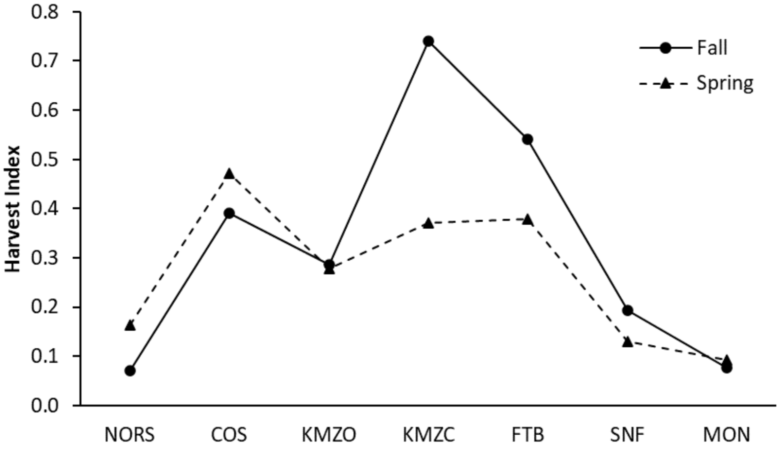

Figure 6.17. Spatial pattern in relative harvest of Trinity River Hatchery UKTR spring Chinook Salmon (dashed line) and UKTR fall Chinook Salmon (KRFC) (solid line) in the ocean commercial fishery. North (left) to South (right). Management zone abbreviations as in Table 7.1.

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[12] The KRFC stock includes UKTR fall Chinook Salmon with a very small contribution of fall Chinook Salmon from the Southern Oregon/Northern California Coast ESU in the lower Klamath River. In this report "UKTR fall Chinook Salmon (KRFC)" is used to refer to fish included in this mixed stock that are likely to be of UKTR origin.

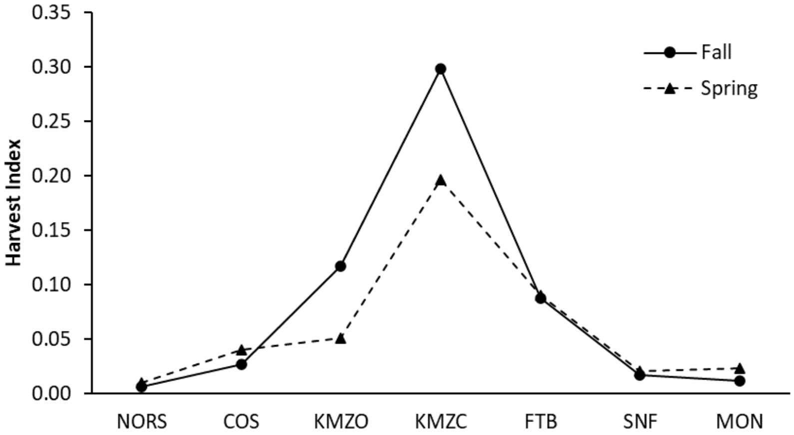

Figure 6.18. Spatial pattern in relative harvest of Trinity River Hatchery UKTR spring Chinook Salmon (dashed line) and UKTR fall Chinook Salmon (KRFC) (solid line) in the ocean recreational fishery. North (left) to South (right). Management zone abbreviations as in Table 7.1

Overall, commercial harvest indices of TRH UKTR spring and UKTR fall Chinook Salmon (KRFC) are comparable in all management areas coast-wide, suggesting the spatial distribution of these two stocks is similar, though the spring ecotype may display a more northerly distribution extension as indicated by slightly higher spring indices compared to fall in the areas north of Humbug Mountain, Oregon.

While season total harvest indices of stocks are similar, there are several time-areas where the harvest index of TRH UKTR spring Chinook Salmon exceeds that for UKTR fall Chinook Salmon (KFRC)(Tables 6.12, 6.13). Unsurprisingly, harvest indices across months demonstrate seasonality. For example, TRH UKTR spring Chinook Salmon harvest indices were elevated above UKTR fall Chinook Salmon (KFRC) harvest indices in spring months (April – May), declined below UKTR fall Chinook Salmon (KFRC) harvest indices during the summer, before increasing again in the fall. The fall increase is presumably due to recruitment of the next age-class of TRH UKTR spring Chinook Salmon into the fishery at a time when mature UKTR fall Chinook Salmon (KFRC) were leaving the ocean to spawn.

Table 6.12. Trinity River Hatchery UKTR spring Chinook Salmon ocean commercial catch per unit effort per 1 million released smolts by management area and month, brood years 1995 – 2012

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Cape Falcon-Florence S. Jetty	0.43	0.18	0.11	0.06	0.02	0.08	0.38	0.37	
Florence S. Jetty-Humbug Mtn.	0.97	0.53	0.37	0.20	0.13	0.44	1.40	0.54	
Humbug Mtn.-OR/CA Border			0.47	0.41	0.35	0.39	0.37		
OR/CA Border-Horse Mtn.			1.10	0.47	0.43	0.30	0.32		
Horse Mtn.-Pt. Arena		0.79	0.79	0.11	0.37	0.25	0.51		
Pt. Arena-Pigeon Pt.		0.19	0.40	0.20	0.09	0.02	0.02	0.02	
Pigeon Pt.-South			0.16	0.04	0.02				

Table 6.13. UKTR fall Chinook Salmon (KRFC) ocean commercial catch per unit effort per 1 million released smolts by management area and month, brood years 1995 – 2012

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Cape Falcon-Florence S. Jetty	0.32	0.05	0.04	0.03	0.06	0.10	0.11	0.12	
Florence S. Jetty-Humbug Mtn.	0.47	0.25	0.11	0.16	0.41	1.20	0.45	0.14	0.02
Humbug Mtn.-OR/CA Border			0.24	0.32	0.39	0.63	0.50		
OR/CA Border-Horse Mtn.			1.22	1.23	0.78	0.50	0.70		
Horse Mtn.-Pt. Arena		0.12	0.57	0.58	1.01	0.41	0.13		
Pt. Arena-Pigeon Pt.			0.21	0.49	0.30	0.05	0.01	0.003	
Pigeon Pt.-South			0.07	0.10	0.09	0.005			

The Fort Bragg management area between Horse Mountain and Point Arena during April experienced a relatively higher TRH UKTR spring Chinook Salmon harvest index than UKTR fall Chinook Salmon (KRFC); however, only one year of data (2007) was available to inform this analysis. The San Francisco management area also experienced a higher TRH UKTR spring Chinook Salmon harvest index during April, though this time-area is no longer available to commercial fisheries because of ESA constraints on Sacramento River winter Chinook Salmon. During May commercial fisheries, TRH UKTR spring Chinook Salmon harvest indices are higher than UKTR fall Chinook Salmon (KRFC) in all management areas coastwide, though only by a small margin in some areas. During September fisheries, the TRH UKTR spring Chinook Salmon harvest indices are greater than UKTR fall Chinook Salmon (KRFC) in northern and central

Oregon, and in the Fort Bragg management area; however, UKTR fall Chinook Salmon (KRFC) harvest index exceeds that for TRH UKTR spring Chinook Salmon in the Klamath Management Zone in both states, possibly due to harvest on the Trinity River fall Chinook Salmon component of KRFC, which has a later average maturity date (O'Farrell et al. 2010).

6.11.2 Recreational Fishery Harvest Indices by Stock and Time-Area

Harvest indices in the recreational ocean salmon fisheries are lower relative to commercial harvest indices for both TRH UKTR spring Chinook Salmon and UKTR fall Chinook Salmon (KFRC). Seasonal total harvest indices for TRH UKTR spring Chinook Salmon are generally similar to UKTR fall Chinook Salmon (KRFC), although lower in most areas. TRH UKTR spring Chinook Salmon harvest indices in the areas between Florence, OR, and Humbug Mountain and South of Pigeon Point were slightly higher than UKTR fall Chinook Salmon (KRFC), though very similar and small (approaching zero). The highest TRH UKTR spring Chinook Salmon harvest indices occurred nearest the Klamath-Trinity basin in the Klamath Management Zone between Humbug Mountain, OR, and Horse Mountain, CA. Central Oregon was the only management area where TRH spring Chinook Salmon harvest indices exceeded UKTR fall Chinook Salmon (KRFC) indices in every month of the fishery (Tables 6.14, 6.15), though the harvest indices are low relative to the Klamath Management Zone or Fort Bragg. Recreational fishery harvest indices also demonstrated seasonality, with TRH spring Chinook Salmon harvest indices generally higher in the spring months, dipping during the summer and increasing in September; however, the variation is less dramatic than the commercial fishery.

6.11.3 Ocean Harvest

In 2006, commercial salmon fishing was closed in the Klamath Management Zone because of a weak UKTR Chinook Salmon stock. In addition, the commercial fishing season along the Oregon coast was severely curtailed (USDI et al. 2012). Weak returns were believed, in part, to result from a large kill of adult spawning fish in the Klamath River between 20 – 27 September 2002. The federal government declared 2002 to be a fishery disaster and released $60 million in relief funds to help compensate losses to commercial fishermen and fishing related businesses in Oregon and California (Upton 2011).

Table 6.14. Trinity River Hatchery UKTR spring Chinook Salmon ocean recreational catch per unit effort per 1 million released smolts by management area and month, brood years 1995 – 2012.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Cape Falcon-Florence S. Jetty				0.017	0.008	0.002	0.012	0.026	
Florence S. Jetty-Humbug Mtn.			0.093	0.021	0.035	0.043	0.060	0.100	
Humbug Mtn.-OR/CA Border			0.076	0.148	0.054	0.022	0.083		
OR/CA Border-Horse Mtn.			0.388	0.329	0.110	0.070	0.162		
Horse Mtn.-Pt. Arena			0.146	0.202	0.064	0.033			
Pt. Arena-Pigeon Pt.		0.071	0.061	0.035	0.007	0.007			
Pigeon Pt.-South	0.047	0.021	0.047	0.020	0.006				

Table 6.15. UKTR fall Chinook Salmon (KRFC) ocean recreational catch per unit effort per 1 million released smolts by management area and month, brood years 1995 – 2012.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Cape Falcon-Florence S. Jetty			0.002	0.001	0.003	0.013	0.011	0.004	
Florence S. Jetty-Humbug Mtn.				0.004	0.023	0.033	0.048	0.044	
Humbug Mtn.-OR/CA Border			0.016	0.037	0.102	0.187	0.272	0.012	
OR/CA Border-Horse Mtn.			0.222	0.298	0.357	0.302	0.249		
Horse Mtn.-Pt. Arena		0.007	0.062	0.148	0.105	0.062			
Pt. Arena-Pigeon Pt.		0.028	0.040	0.036	0.016	0.003			
Pigeon Pt.-South	0.008	0.018	0.015	0.005	0.003				

The UKTR fall Chinook Salmon (KRFC) stock was declared overfished in 2018 by the Pacific Fishery Management Council. Currently, the stock remains classified as "overfished" prompting the Council to adopt a rebuilding plan. The rebuilding plan includes application of the current UKTR fall Chinook Salmon KRFC harvest control rule to set maximum allowable exploitation rates and minimum escapement values based on forecasted abundance. Although natural area escapement in 2020 was much less than the spawning fish abundance at maximum sustainable yield (S_{MSY}) of 40,000, escapement was still approximately 20,000 adults. Low escapement has been observed in the last four years. Exploitation rates have generally been at or below preseason projections. Poor ocean conditions are implicated for at least some of the observed decline (Thom 2020).

All Chinook Salmon ocean fisheries off the California coast are “mixed-stock fisheries,” meaning that Chinook Salmon from different locations and different ESUs co-occur in the ocean, and are therefore mixed in harvest, in various proportions depending on the stock, time of year, and geographic location. Different Chinook Salmon stocks (e.g., UKTR spring and fall Chinook Salmon, CV Chinook Salmon) are externally alike in appearance, and the specific stock to which any given fish belongs cannot determined at the time of harvest. Stock-identification of ocean harvested fish is limited to evaluation of CWTs recovered from hatchery-origin fish during standardized, long-term, and coastwide ocean fishery monitoring programs.

The Department evaluated information on UKTR spring Chinook Salmon ocean distribution and harvest using coded-wire tags from recovered Trinity River Hatchery-produced UKTR spring Chinook Salmon. Unfortunately, spawning age-composition and cohort reconstruction analyses necessary to estimate total ocean abundance and natural-origin harvest are currently unavailable for UKTR spring Chinook Salmon. While total ocean impacts on the stock are unknown, harvest of TRH UKTR spring Chinook Salmon can be used to evaluate minimum ocean fishery effects on the stock. However, although TRH has released tagged UKTR spring Chinook Salmon since at least 1976 (Table 6.16), interannual variation in fish released and proportion tagged make accurate evaluation over the entire period difficult. A description of the methods used in this section can be found in Appendix B.

Trinity River Hatchery has released CWT tagged spring Chinook Salmon annually since at least 1976 (Table 6.16); however, there is considerable interannual variation in the total number of fish released and the proportion tagged until 1995. For example, a little over 35,000 spring Chinook Salmon were released at a 98% CWT tag rate in 1980, followed by over 1.6 million released at a 17% tag rate the following year.

Ocean salmon fisheries on average harvested 0.1% (range: 0-0.39%) of the total released TRH spring Chinook Salmon annually for brood years 1995 – 2012 (ocean harvest years 1997 – 2017). Approximately 82% of the total ocean harvest occurred in the commercial fishery for broods 1995 – 2012 (complete broods marked and tagged at comparable rates, 86% long-term), with an equal split between Oregon and California harvest (50.5% Oregon, 49.5% California). The remaining 18% of UKTR spring Chinook Salmon harvested were taken by the recreational Salmon fishery, with over three quarters (77%) taken in California waters for broods 1995 – 2012 (14% long-term).

Ocean salmon fishery harvest of natural-origin UKTR spring Chinook Salmon is currently unavailable due to the lack of spawning age-composition and cohort reconstruction analyses. Those analyses would also be required as a prerequisite for determining ocean abundance of UKTR spring Chinook Salmon and total ocean fishery impacts (i.e., hatchery- and natural-origin harvest and incidental mortality associated with fisheries).

Table 6.16. Upper Klamath-Trinity River spring Chinook Salmon coded-wire tag releases from Trinity River Hatchery and ocean harvest; brood years 1976 – 2015[a].

Brood Year	Number Tagged	Total Released	Percent Tagged	Subtotal - Commercial		Subtotal - Recreational		Total Ocean Harvest [b]			Proportion Harvested
				OR	CA	OR	CA	Com.	Rec.	Total	
1976	56,840	58,000	98%	139	408	3	6	547	8	556	0.96%
1977	95,230	100,000	95%	75	174	6	3	249	9	258	0.26%
1978	702,821	1,591,546	44%	801	3400	146	67	4,201	213	4,414	0.28%
1979	490,888	540,440	91%	1296	2122	141	174	3,418	316	3,734	0.69%
1980	34,601	35,128	98%	24	57	25	11	81	36	117	0.33%
1981	281,272	1,607,743	17%	173	374	80	107	547	187	734	0.05%
1982	242,655	484,167	50%	816	606	70	274	1,423	345	1,768	0.37%
1983	90,293	318,132	28%	2840	3687	238	298	6,526	536	7,063	2.22%
1984	98,568	563,970	17%	6372	6617	1120	760	12,989	1,880	14,869	2.64%
1985	293,578	3,789,170	8%	6912	9766	645	1295	16,678	1,940	18,618	0.49%
1986	298,143	1,485,468	20%	1799	1336	177	490	3,135	667	3,802	0.26%
1987	185,718	2,555,300	7%	155	118	43	107	272	150	422	0.02%
1988	280,518	2,547,494	11%	0	84	0	76	84	76	160	0.01%
1989	288,968	2,074,151	14%	68	57	22	0	124	22	146	0.01%
1990	291,547	2,961,379	10%	29	173	31	131	202	162	364	0.01%
1991	309,074	585,489	53%	0	33	9	3	33	12	45	0.01%
1992	324,994	973,479	33%	546	711	67	440	1,258	507	1,764	0.18%
1993	333,581	2,300,827	14%	224	853	94	201	1,076	295	1,372	0.06%
1994	226,727	1,934,581	12%	204	112	43	54	316	97	413	0.02%
1995	298,152	1,471,630	20%	248	70	16	80	317	96	414	0.03%
1996	329,211	1,451,117	23%	124	42	0	46	167	46	213	0.01%
1997	356,662	1,719,651	21%	927	1356	29	387	2,282	416	2,698	0.16%
1998	314,570	1,563,206	20%	241	141	22	115	381	137	518	0.03%
1999	282,910	1,334,212	21%	1987	1121	130	283	3,107	413	3,520	0.26%
2000	360,767	1,513,728	24%	1740	3643	123	412	5,382	535	5,918	0.39%
2001	357,615	1,460,536	24%	1967	1603	231	391	3,570	622	4,193	0.29%

Brood Year	Number Tagged	Total Released	Percent Tagged	Subtotal - Commercial		Subtotal - Recreational		Total Ocean Harvest [b]			Proportion Harvested
2002	350,893	1,430,052	25%	1595	864	239	470	2,459	708	3,168	0.22%
2003	371,656	1,514,406	25%	213	135	12	166	348	178	526	0.03%
2004	360,662	1,544,949	23%	143	218	116	352	361	468	829	0.05%
2005	370,715	1,532,096	24%	0	0	0	0	0	0	0	0%
2006	330,477	1,364,666	24%	109	6	0	0	115	0	115	0.01%
2007	274,084	1,125,081	24%	188	62	23	23	250	46	296	0.03%
2008	333,967	1,367,340	24%	58	64	24	34	122	58	180	0.01%
2009	269,877	1,105,109	24%	278	633	84	460	912	544	1,456	0.13%
2010	265,830	1,140,452	23%	736	295	23	239	1,031	261	1,292	0.11%
2011	264,976	1,202,411	22%	315	397	9	44	712	53	765	0.06%
2012	361,576	1,525,916	24%	46	53	0	18	99	18	116	0.01%
2013[c]	362,633	1,519,977	24%	21	26	0	11	48	11	59	NA
2014[d]	348,977	1,477,842	24%	0	13	18	28	13	46	59	NA
2015[e]	357,601	1,517,947	24%	0	0	0	17		17	17	NA

[a] Recoveries from all ocean areas, including north of Cape Falcon, OR.

[b] Recoveries expanded for hatchery tagging and sample rates.

[c] Incomplete brood. Age-5 recoveries not available.

[d] Incomplete brood. Age-4 and age-5 recoveries not available.

[e] Incomplete brood. Age-3, age-4, and age-5 recoveries not available.

The Department evaluated ocean fishery harvest of TRH hatchery-origin UKTR spring Chinook Salmon using CWT data (see UKTR spring Chinook Salmon ocean distribution). Recoveries expanded for the proportion of total released fish that were CWT tagged and adipose fin-clipped and sample rate (the proportion of the fishery by time and area that was observed) were summarized by ocean salmon fishery management area as described in PFMC's salmon Fishery Management Plan (FMP).

To inform an overall perspective of ocean salmon fishery harvest, the cumulative harvest of UKTR spring Chinook Salmon was summarized for brood years 1995 through 2012 (18 broods) across 21 harvest years (1997 – 2017). For aggregate brood years 1995 – 2012, the majority of hatchery-origin UKTR spring Chinook Salmon were taken by commercial ocean salmon fisheries (83%, Table 6.17), half of which occurred in Oregon primarily between Florence South Jetty and Humbug Mountain (Coos Bay area; 66% of Oregon commercial harvest). In California, the troll fisheries between Horse Mountain (near Shelter Cove, Humboldt County) and Pigeon Point (San Mateo County) harvested the majority of UKTR spring Chinook Salmon (80% of California commercial harvest), with approximately 38% harvested in the area between Horse Mountain and Point Arena (Fort Bragg management area) and 42% between Point Arena (Sonoma County) and Pigeon Point (San Francisco management area). Relatively few UKTR spring Chinook Salmon were commercially harvested in the Klamath Control Zone between Humbug Mountain, OR and Humboldt South Jetty, likely due to limited fishing opportunity in this area because of constraints intended to protect UKTR fall Chinook Salmon (KRFC) and/or California coastal Chinook Salmon.

Table 6.17. Cumulative UKTR spring Chinook Salmon harvest and proportion of all-stocks by ocean fishery, management area, and state; brood years 1995 – 2012.

Management area	Commercial Harvest	Prop.	Recreational Harvest	Prop.	Total Harvest	Prop.
Cape Falcon-Florence S. Jetty	3,074	0.23%	154	0.14%	3,228	0.22%
Florence S. Jetty-Humbug Mtn.	6,999	0.67%	391	0.32%	7,390	0.63%
Humbug Mtn.-OR/CA Border	499	0.66%	347	0.37%	846	0.50%
Oregon subtotal	10,571	0.43%	893	0.27%	11,464	0.41%
Proportion OR	50%		20%		45%	
OR/CA Border-Horse Mtn.*	378	0.39%	1,656	0.65%	2,033	0.58%
Horse Mtn.-Pt. Arena	4,055	0.45%	780	0.33%	4,835	0.42%
Pt. Arena-Pigeon Pt.	4,554	0.19%	659	0.06%	5,213	0.15%
Pigeon Pt.-South	1,716	0.16%	425	0.09%	2,141	0.14%
California subtotal	10,702	0.24%	3,520	0.17%	14,222	0.22%
Proportion CA	50%		80%		55%	
Total	21,273 82.8%	0.30%	4,412 17.2%	0.19%	25,686	0.27%

* OR/CA Border to Humboldt South Jetty for commercial fisheries.

The ocean recreational fishery contributed the remaining 17% of cumulative UKTR spring Chinook Salmon harvest for brood years 1995 – 2012, primarily in California (80%), and specifically in the area between the OR/CA Border and Horse Mountain (38% of the total harvest), an area encompassing the Klamath River.

Hatchery-origin UKTR spring Chinook Salmon are not a target stock for ocean salmon fisheries and contribute less than 1% to total (all-stocks) salmon harvest in all ocean management areas and fisheries. Overall, hatchery-origin UKTR spring Chinook Salmon contribute 0.27% to total ocean salmon harvest south of Cape Falcon, OR, 0.22% in California and 0.41% in Oregon south of Cape Falcon.

While cumulative harvest of UKTR spring Chinook Salmon from brood years 1995 – 2012 can provide a high-level overview of ocean salmon fisheries, it is confounded by variable annual amounts of fishing opportunity overall and opportunity among management areas. Ocean salmon fishing opportunity and total harvest of all stocks varies considerably based on annual management objectives, geographic location of open areas, and the time of year available to fishing.

Interannual harvest of UKTR spring Chinook Salmon varied between brood years 1995 – 2012, potentially as a result of inconsistent ocean salmon fishery regulations geographically and by time of year. The Department evaluated the potential influence of variable days open to fishing, UKTR spring Chinook Salmon catch per day and found no relationship in either commercial (Figure 6.19, R^2=0.09) or recreational (Figure 6.20, R^2=0.25) ocean salmon fisheries, suggesting that UKTR spring Chinook Salmon are not equally distributed in time and/or space, and finer scale stratification is likely warranted. This analysis found similar results when it compared UKTR spring Chinook Salmon harvest to total days fished (i.e. fishing pressure), further showing that time on the water (fishing opportunity) alone is not a good indicator of potential UKTR spring Chinook Salmon harvest in the absence of a time-area-fishery-specific analysis.

In the commercial ocean salmon fisheries, harvest of UKTR spring Chinook Salmon ranged from less than one fish per 1,000 total Chinook Salmon harvested up to 28 UKTR spring Chinook Salmon per 1,000 all stocks (Table 6.18). Several of the open areas and times in this analysis had no harvest of hatchery-origin UKTR spring Chinook Salmon (indicated as dashes in Table 6.14) between brood years 1995 – 2012. The highest recovery rate, 28 UKTR spring Chinook Salmon per 1,000 total all-stocks, occurred during April in the Fort Bragg management area between Horse Mountain and Point Arena; however, this fishery was held only in 2007. The area between the OR/CA Border to Humboldt South Jetty, California's portion of the Klamath Management Zone (KMZ), during May represented the second highest commercial recovery rate (19 UKTR spring Chinook Salmon per 1,000 total all-stocks), but like Fort Bragg in April, this represents only one year of data (2013).

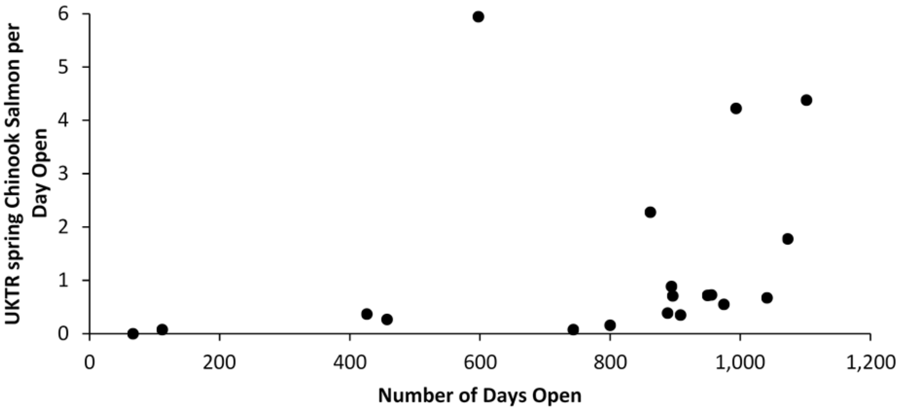

Figure 6.19. Commercial ocean harvest of UKTR spring Chinook Salmon per day open to fishing (all management areas south of Cape Falcon, Oregon, combined).

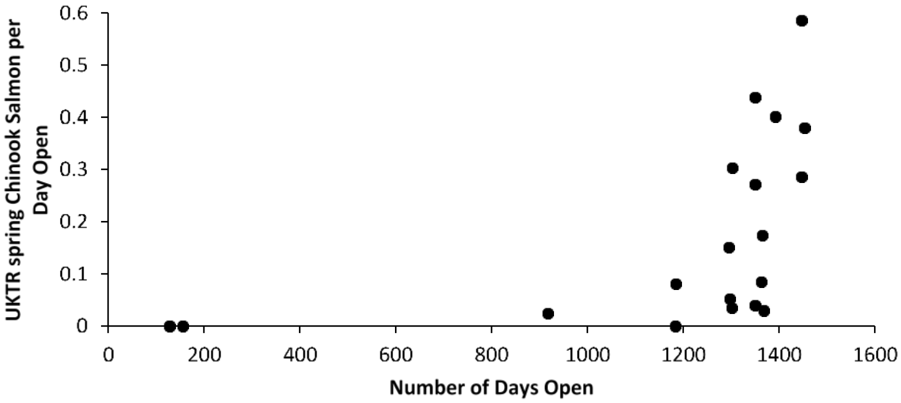

Figure 6.20. Recreational ocean harvest of UKTR spring Chinook Salmon per day open to fishing (all management areas south of Cape Falcon, Oregon, combined).

Ordinarily, the California KMZ commercial salmon fishery is open only during September, if at all. Note that ocean commercial fisheries south of Point Arena during April are discontinued per the SRWC Biological Opinion. Allowable Oregon state-water commercial fisheries during November and December are not shown because no UKTR spring Chinook Salmon were harvested there.

Table 6.18. Commercial ocean harvest of UKTR spring Chinook Salmon per 1,000 all-stocks by management area and month; brood years 1995 – 2012.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Cape Falcon-Florence S. Jetty	5	3	2	1	0.3	1	5	4
Florence S. Jetty-Humbug Mtn.	12	8	6	3	2	4	15	11
Humbug Mtn.-OR/CA Border	-	-	7	9	7	8	7	-
OR/CA Border-Horse Mtn.			19	6	9	4	5	
Horse Mtn.-Pt. Arena		28	10	2	3	4	6	
Pt. Arena-Pigeon Pt.		1	4	2	1	1	1	1
Pigeon Pt.-South		-	3	1	0.4	-	-	

Recreational ocean harvest of UKTR spring Chinook Salmon ranged from less than one fish per 1,000 total Chinook Salmon harvested up to 13 UKTR spring Chinook Salmon per 1,000 (Table 6.19), with highest recovery rates during May and October in the Florence South Jetty to

Humbug Mountain (Coos Bay; 13 per 1,000) and May in the OR/CA Border to Horse Mountain area (CA-portion of the KMZ; 13 per 1,000). Like the commercial fishery, several open recreational areas/times did not harvest hatchery-origin UKTR spring Chinook Salmon (indicated by dashes) between brood years 1995 – 2012. Some allowable recreational ocean fisheries are not shown as no UKTR spring Chinook Salmon were harvested there (e.g., November outside of the KMZ). Note that ocean recreational fisheries south of Point Arena prior to April are no longer permitted per the Sacramento River Winter Chinook Biological Opinion.

Table 6.19. Recreational ocean harvest of UKTR spring Chinook Salmon per 1,000 of all stocks by management area; brood years 1995 – 2012.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Cape Falcon-Florence S. Jetty	-	-	-	4	1	0.3	2	2
Florence S. Jetty-Humbug Mtn.	-	-	13	2	3	3	6	13
Humbug Mtn.-OR/CA Border			6	9	3	1	6	-
OR/CA Border-Horse Mtn.			13	10	4	3	5	
Horse Mtn.-Pt. Arena	-	-	6	7	2	1	-	-
Pt. Arena-Pigeon Pt.	-	2	2	1	0.2	0.3	-	-
Pigeon Pt.-South	2	1	2	1	0.2	-	-	-

While the total harvest of UKTR spring Chinook Salmon is higher in the commercial fishery, the rate of harvest per total all-stocks is reasonably comparable across geographic locations and is also comparable to the recreational fishery (Tables 6.20 – 6.23). No single fishery, area, or time of year appeared to dominate ocean harvest of hatchery-origin UKTR spring Chinook Salmon. However, the highest UKTR spring Chinook Salmon recovery rate areas may not represent the time-area-fishery with the highest total harvest, as harvest differs among years, months, geographic locations, and fishery type dependent on target-stock, ocean abundance, and fishing opportunity (i.e., days open to fishing in a given location and time of year). The Department evaluated potential ocean salmon fishery harvest of UKTR spring Chinook Salmon across a range of fishing seasons by calculating the average harvest of all-stocks by management area and month coupled with hatchery-origin UKTR spring Chinook Salmon ocean recovery rates (i.e., the number of UKTR spring Chinook Salmon harvested per 1,000 all-stocks). The Department urges caution when interpreting this information due to the inter-annual variability in total harvest rates and fishing opportunity (i.e., the number of days open to fishing).

In general, should future commercial ocean salmon fishing opportunity and total all-stock harvest be similar to the average of the previous twenty-one years the Department would expect that more UKTR spring Chinook Salmon could potentially be harvested in May between

Horse Mountain and Pigeon Point (Table 6.21; Fort Bragg and San Francisco management areas) than at other times and areas. While the recovery rate of UKTR spring Chinook Salmon in the San Francisco area is less than half the recovery rate in Fort Bragg, the total harvest of all-stocks is over double, resulting in similar potential average harvest of UKTR spring Chinook Salmon. Likewise, if recreational harvest of all-stocks and fishing opportunity remains similar, UKTR spring Chinook Salmon harvest could potentially be highest during May and June in the California KMZ.

Table 6.20. Average commercial harvest in numbers of Chinook Salmon by management area and month, all stocks; harvest years 1997 – 2017.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Cape Falcon-Florence S. Jetty	7,319	5,275	14,647	12,771	7,455	14,384	10,716	6,998
Florence S. Jetty-Humbug Mtn.	7,479	7,490	10,195	10,739	5,663	16,017	8,455	3,406
Humbug Mtn.-OR/CA Border	25	47	1,240	1,036	1,090	931	739	446
OR/CA Border-Horse Mtn.			2,688	2,924	1,979	1,629	3,665	
Horse Mtn.-Pt. Arena		748	19,582	17,046	36,285	21,641	10,985	
Pt. Arena-Pigeon Pt.		3,266	40,130	40,012	45,560	16,089	10,590	1,642
Pigeon Pt.-South		5,947	29,859	16,832	12,498	1,130	373	

Table 6.21. Average[a] commercial harvest of hatchery-origin UKTR spring Chinook Salmon by management area and month; brood years 1995 – 2012.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Cape Falcon-Florence S. Jetty	35	18	24	12	2	14	50	30
Florence S. Jetty-Humbug Mtn.	90	57	63	32	11	71	126	36
Humbug Mtn.-OR/CA Border	0	0	8	9	8	8	5	
OR/CA Border-Horse Mtn.			51	19	17	7	17	
Horse Mtn.-Pt. Arena		21	193	26	121	80	66	
Pt. Arena-Pigeon Pt.		5	172	68	44	9	6	1
Pigeon Pt.-South		0	81	9	5	0	0	

[a] Average harvest of all stocks times the TRH UKTR spring Chinook Salmon recovery rate.

Table 6.22. Average recreational harvest in numbers of Chinook Salmon by management area and month from all-stocks; harvest years 1997 – 2017.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Cape Falcon-Florence S. Jetty	33	24	101	277	1,635	1,420	1,381	907
Florence S. Jetty-Humbug Mtn.	3	14	75	830	2,500	1,966	641	15
Humbug Mtn.-OR/CA Border			277	812	1,026	1,761	626	530
OR/CA Border-Horse Mtn.			1,965	3,821	3,368	3,816	1,095	
Horse Mtn.-Pt. Arena	238	461	1,243	3,162	5,211	2,401	315	23
Pt. Arena-Pigeon Pt.	1,282	3,938	7,068	9,442	18,936	9,260	4,706	1,990
Pigeon Pt.-South	4,577	10,215	3,251	4,521	4,747	744	203	44

Table 6.23. Average[a] recreational harvest of hatchery-origin UKTR spring Chinook Salmon by management area and month; brood years 1995 – 2012.

Management Area	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Cape Falcon-Florence S. Jetty	0	0	0	1	2	0	2	2
Florence S. Jetty-Humbug Mtn.	0	0	1	1	6	7	4	0
Humbug Mtn.-OR/CA Border			2	8	3	2	4	0
OR/CA Border-Horse Mtn.			25	40	12	10	6	
Horse Mtn.-Pt. Arena	0	0	8	22	10	3	0	0
Pt. Arena-Pigeon Pt.	0	9	11	8	3	2	0	0
Pigeon Pt.-South	8	8	8	3	1	0	0	0

[a] Average harvest of all-stocks times the TRH UKTR spring Chinook Salmon recovery rate.

In summary, based on ocean catch of TRH UKTR spring Chinook Salmon, overall ocean harvest of UKTR spring Chinook Salmon appears to be small and comprises a very small percentage of ocean harvest. Management measures are in place to both directly and indirectly protect UKTR spring Chinook Salmon through weak stock management (See Section 7.4.1).

6.11.4 Tribal In-River Harvest

Only UKTR fall Chinook Salmon (KRFC) are currently managed under the Pacific Fishery Management Council (PSMFC). The stock is allocated under a 50:50 sharing agreement. Because PFMC does not manage UKTR spring Chinook Salmon as a separate stock, the state and the tribes are each responsible for harvest management of spring Chinook Salmon in the absence of PSMFC allocation. In-river harvest, both recreational and tribal are governed by quotas determined by the PMFC that target in-river escapement objectives.

Salmon are a critically important cultural and nutritional resource for the Klamath River tribes. Prior to European colonization and later dam construction and habitat modification, salmon supported the traditional hunter-gatherer societies of native peoples in the Klamath basin. Hoopa and Yurok tribal fisheries are conducted on tribal lands.

The heaviest fishery on Yurok lands is currently in the estuary below the Highway 101 bridge, although there are fishers spread out all the way upstream to Trinity River confluence. The Hoopa fishery is spread out throughout the Hoopa Valley Tribe Reservation. There is also a

Karuk tribal fishery. However, the Karuk Tribe does not currently provide harvest data to the Department for inclusion into the UKTR fall Chinook Salmon megatable. The impact of Karuk tribal fisheries on UKTR spring Chinook Salmon is likely small since their fishery is upstream of the Trinity River confluence and so does not contact Trinity basin UKTR spring Chinook Salmon (W. Sinnen, CDFW, Personal Communication, January 2020).

In 1986, the Hoopa Valley Tribe adopted the *Hoopa Tribal Fishing Ordinance* to allow the tribe to exercise jurisdictional control over fisheries on tribal lands. The ordinance contains elements that direct tribal control over who can fish, identification of authorized persons, type of gear, seasons, and other provisions. Under this ordinance, for the 1986 season, salmon fishing was allowed for all species of anadromous fish from 1 July through 24 December, 24 hours per day, 7 days per week, except for a period to collect abandoned or lost fishing gear. The Department is not aware of annual fishery management plans promulgated by the Hoopa Tribal Fisheries Department or Tribal Council to govern annual fishing restrictions or harvest.

The Yurok Tribe produces an annual harvest management plan primarily focused on UKTR fall Chinook Salmon. However, the Yurok Tribe also implements management to protect UKTR spring Chinook Salmon through closures and other tribal fishery management actions.

In cooperation with tribal fishery agencies, the Department maintains records of Hoopa and Yurok tribal harvest of UKTR spring Chinook Salmon. Figure 6.21 and Table 6.24 show the annual tribal harvest for the Hoopa and Yurok tribes from 1980-2017. Annual tribal harvest for both Hoopa and Yurok tribes has typically ranged from a few hundred to several thousands of UKTR spring Chinook Salmon. Yurok tribal harvest was much larger in 2001 and 2002, in the tens of thousands. Average harvest was 1,458 UKTR spring Chinook Salmon for the Hoopa Tribe, and 4,422 for the Yurok Tribe.

Table 6.24. Hoopa and Yurok tribal harvest of UKTR spring Chinook Salmon, 1980 – 2017.

Year	Hoopa Tribe	Yurok Tribe	All Tribal Harvest
1981	1,107	1,717	2,824
1982	725	2,440	3,165
1983	75	510	585
1984	380	247	627
1985	1,115	1,074	2,189
1986	2,022	692	2,714
1987	4,268	1,646	5,914
1988	2,811	2,918	5,729
1989	1,998	4,745	6,743
1990	889	1,413	2,302
1991	263	283	546
1992	346	396	742
1993	228	550	778
1994	255	501	756
1995	1,268	2,592	3,860
1996	1,188	5,905	7,093
1997	1,251	5,440	6,691
1998	471	2,338	2,809
1999	789	2,392	3,181
2000	1,897	3,207	5,104
2001	4,210	14,890	19,100
2002	3,232	12,266	15,498
2003	2,384	6,690	9,074
2004	2,006	3,610	5,616
2005	1,875	2,258	4,133
2006	1,690	2,718	4,408
2007	1,355	4,494	5,849
2008	1,404	2,029	3,433
2009	1,838	1,762	3,600
2010	1,744	3,279	5,023
2011	2,390	2,615	5,005
2012	2,668	3,622	6,290
2013	1,221	3,760	4,981
2014	1,818	3,161	4,979
2015	1,102	2,577	3,679
2016	693	1,001	1,694
2017	420	889	1,309
Averages	**1,497**	**3,044**	**4,541**
max	**4,268**	**14,890**	**19,100**
min	**75**	**247**	**546**

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UKTR fall Chinook Salmon tribal net fishery harvest is shown in Table 6.25. Although highly variable over the monitoring period, average take is approximately 20% of the total UKTR fall Chinook Salmon returns. This rate of harvest is moderately large given the overall abundance of UKTR fall Chinook Salmon and the ESU as a whole.

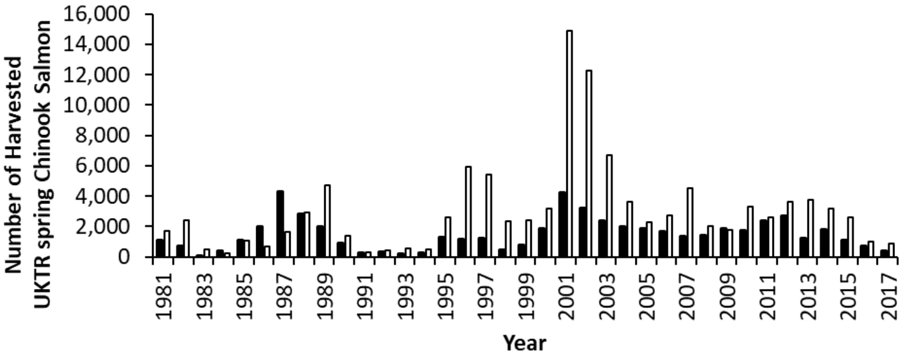

Figure 6.21. Tribal UKTR spring Chinook Salmon in-river harvest, 1981 – 2017. Black bars are Hoopa tribal harvest and white bars are Yurok tribal harvest.

Table 6.25. UKTR fall Chinook Salmon net harvest, 1978 – 2018.

Year	Grilse	Adults	Total	Rate	Year	Grilse	Adults	Total	Rate
1978			20,000	0.173	1999	271	14,660	14,931	0.212
1979			15,000	0.238	2000	303	29,415	29,718	0.13
1980	987	12,013	13,000	0.158	2001	399	38,645	39,044	0.197
1981	2,465	33,033	35,498	0.327	2002	126	24,574	24,700	0.145
1982	1,799	14,482	16,281	0.154	2003	44	30,034	30,078	0.154
1983	163	7,890	8,053	0.131	2004	168	25,803	25,971	0.293
1984	455	18,670	19,125	0.344	2005	70	8,016	8,086	0.12
1985	1,555	11,566	13,121	0.098	2006	415	10,283	10,698	0.121
1986	854	25,127	25,981	0.108	2007	21	27,573	27,594	0.206
1987	415	53,096	53,511	0.235	2008	641	22,259	22,900	0.239
1988	578	51,651	52,229	0.242	2009	178	28,387	28,565	0.254
1989	191	45,565	45,756	0.343	2010	428	29,887	30,315	0.282
1990	190	7,906	8,096	0.201	2011	1,322	26,353	27,675	0.148
1991	62	10,198	10,260	0.298	2012	177	95,386	95,563	0.302
1992	366	5,785	6,151	0.152	2013	259	63,036	63,295	0.353
1993	175	9,636	9,811	0.151	2014	348	25,967	26,315	0.144
1994	293	11,692	11,985	0.153	2015	496	28,048	28,544	0.34
1995	557	15,557	16,114	0.066	2016	160	5,160	5,320	0.194
1996	190	56,476	56,666	0.306	2017	266	1,880	2,146	0.04
1997	35	12,087	12,122	0.132	2018	308	14,769	15,077	0.146
1998	53	10,187	10,240	0.107	**Avg**	**456**	**24,686**	**24,769**	**0.198**

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6.11.5 Non-Tribal In-River Harvest

Because there is no PSMFC allotment of UKTR spring Chinook Salmon, the state has sole responsibility for their management in the basin. The Fish and Game Commission is the only entity that promulgates regulations specific to UKTR spring Chinook Salmon. Generally, regulations have been conservative for UKTR spring Chinook Salmon, including closures and smaller bag and possession limits than for UKTR fall Chinook Salmon.

The Department maintains records of non-tribal sport harvest of UKTR spring Chinook Salmon in the Klamath and Trinity Rivers (Table 6.26 and Figure 6.22). Beginning in 2010, the Department implemented a dedicated creel survey focused on UKTR spring Chinook Salmon harvest in the lower Klamath River. Prior to 2010, harvest estimates only captured the end of UKTR spring Chinook Salmon harvest season in early August.

Most of the sport fishing for UKTR spring Chinook Salmon is in the lower 32.2 km (20 miles) of the Klamath River and in the Upper Trinity River, particularly at the Burnt Ranch and Greys Falls area, and the area from Junction City to Lewiston Dam. There are sportfishing closures above Weitchpec on the Klamath (Trinity Confluence) and the Lower Trinity River below the South Fork Trinity River. These closures were specifically put into place to protect wild UKTR spring Chinook Salmon.

Figure 6.22 shows that sport harvest has declined in relation to the peak harvest period in the mid-1980s; however, the cyclic pattern of harvest since that time shows about the same highs and lows at a lower average. Averages for the entire period show that sport harvest is largest in the Trinity River (1,007 spring Chinook Salmon annually) and lower in the Klamath River (468 spring Chinook Salmon annually). Recent harvest (since 2012) has declined; however, the pattern and amount of decline is similar to that seen in previous declines (e.g., 1989 – 92 and 2002 – 2009). The lowest numbers during the recent decline are marginally higher than those in the lowest point of previous decline periods. Although creel surveys prior to 2010 were limited, available data suggest that until about 2009 (and again in 2012), most of the sport harvest was in the Trinity River. Recent sport harvest has shifted to a larger proportion taken in the lower Klamath.

Sport harvest totals for UKTR fall Chinook Salmon (Table 6.27) show that in-river harvest has varied. The average harvest rate over the monitoring period is around 8%, which is moderate in relation to overall abundance of the fall component and the UKTR Chinook Salmon ESU as a whole.

Overall sport harvest of both UKTR spring and fall Chinook Salmon is moderate in comparison to overall ESU-level abundance in the Klamath basin. Relatively larger harvest of UKTR spring Chinook Salmon in the Trinity River is likely supportable due to the presence of larger numbers there and the presence of hatchery-origin UKTR spring Chinook Salmon from TRH. However, given the low abundance of UKTR spring Chinook Salmon in the Klamath River (Salmon River), even the relatively small numbers of spring ecotype fish harvested there deserve more scrutiny.

Table 6.26. Non-tribal in-river UKTR spring Chinook Salmon sport harvest in the Klamath and Trinity rivers, 1980 – 2017.

Year	Klamath Sport Harvest	Trinity Sport Harvest	Total Sport Harvest
1980		424	424
1981		2,156	2,156
1982		756	756
1983			
1984		414	414
1985		863	863
1986		4,171	4,171
1987		9,361	9,361
1988	148	8,840	8,988
1989	145	2,630	2,775
1990	17	845	862
1991	108	336	444
1992	17	298	315
1993		423	423
1994	96	454	550
1995	464		464
1996	670	1,513	2,183
1997	786	1,330	2,116
1998	412	1,680	2,092
1999	645	667	1,312
2000	161	1,807	1,968
2001	898	1,164	2,062
2002	812	1,871	2,683
2003	246	2,033	2,279
2004	33	889	922
2005	93	961	1,054
2006	158	17	175
2007	97	565	662
2008	248	306	554
2009	48	442	490
2010	749	463	1,212
2011	1,587	112	1,699
2012	775	2,139	2,914
2013	1,362	243	1,605
2014	1,276	226	1,502
2015	533	190	723
2016	532	216	748
2017	452	104	556
2018	992	265	1,257
Average	**485**	**1,130**	**1,544**
max	**1,587**	**9,361**	**9,361**
min	**17**	**17**	**175**

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Table 6.27. Non-tribal in-river UKTR fall Chinook Salmon sport harvest in the Klamath and Trinity rivers, 1978 – 2018.

Year	Grilse	Adults	Total	Rate
1978	2,082	1,694	3,776	0.033
1979	2,181	2,141	4,322	0.069
1980	5,891	4,496	10,387	0.126
1981	7,252	5,983	13,235	0.122
1982	12,484	8,339	20,823	0.196
1983	351	4,235	4,586	0.075
1984	952	3,340	4,292	0.077
1985	11,195	3,582	14,777	0.110
1986	9,408	21,027	30,435	0.127
1987	5,436	20,169	25,605	0.112
1988	5,411	22,203	27,614	0.128
1989	2,267	8,775	11,042	0.083
1990	2,100	3,553	5,653	0.140
1991	686	3,383	4,069	0.118
1992	4,120	1,002	5,122	0.127
1993	1,925	3,172	5,097	0.079
1994	2,556	1,832	4,388	0.056
1995	4,420	6,081	10,501	0.043
1996	2,312	12,766	15,078	0.081
1997	2,409	5,676	8,085	0.088
1998	1,108	7,710	8,818	0.093
1999	1,616	2,282	3,898	0.055
2000	1,582	5,650	7,232	0.032
2001	1,500	12,134	13,634	0.069
2002	870	10,495	11,365	0.067
2003	814	9,680	10,494	0.054
2004	2,741	4,003	6,744	0.076
2005	1,030	1,985	3,015	0.045
2006	5,527	62	5,589	0.063
2007	369	6,312	6,681	0.050
2008	4,308	1,919	6,227	0.065
2009	2,214	5,651	7,865	0.070
2010	1,831	3,035	4,866	0.045
2011	9,981	4,147	14,128	0.076
2012	3,875	13,876	17,751	0.056
2013	2,260	19,800	22,060	0.123
2014	3,364	5,386	8,750	0.048
2015	1,605	7,842	9,447	0.113
2016	162	1,310	1,472	0.054
2017	42	71	113	0.002
2018	2,206	4,075	6,281	0.061
Average:	**3,279**	**6,607**	**9,886**	**0.081**

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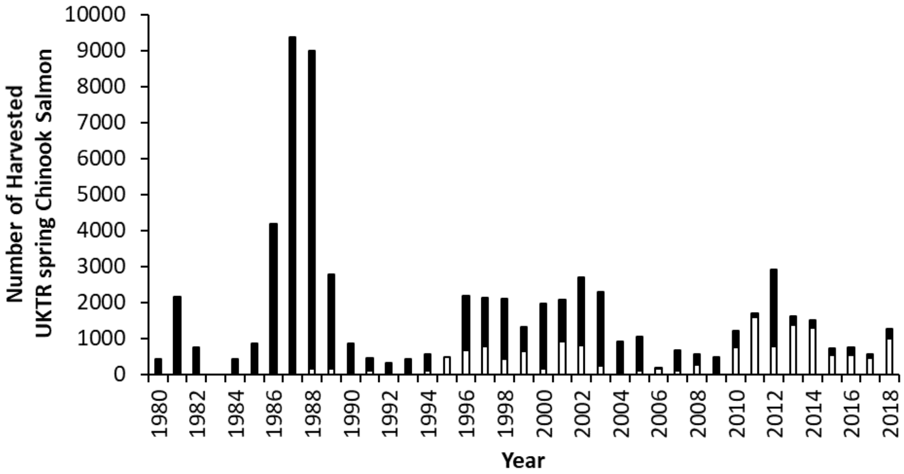

Figure 6.22. Number of UKTR spring Chinook Salmon harvested in non-tribal, in-river, sport fisheries. Black bars are Trinity River harvest and white bars are Klamath River harvest.

6.12 Timber Harvest

Timber harvest has been studied in the latter portion of the twentieth century regarding its effect on anadromous salmonids of the Pacific Northwest, including those inhabiting coastal watersheds in California (Burns 1972; Meehan 1991; Murphy 1995).

Legacy forestry practices are often cited as cause for declines in anadromous salmonid numbers and quality of habitat. In 1964, historic precipitation acting on clear-cut mountainsides led to catastrophic landslides that contributed millions of cubic yards of sediment to streams, destroying salmonid spawning and rearing habitat (Campbell and Moyle 1991). Overall, though, the UKTR Chinook Salmon ESU is not in decline and declines in the spring ecotype are primarily due to factors other than timber harvest.

6.13 Gravel Extraction

Sand, gravel, and crushed rock are the most economically important mineral resources in the region. There are many small aggregate production sites. Asbestos, chromium, clay, copper, diatomite, gold, graphite, and mercury are also mined in the Klamath basin.

Instream gravel mining typically occurs within lower gradient depositional portions of rivers near population centers where aggregate is often processed into sand, gravel, crushed rock (i.e., road base) and sorted gravel. Gravel mining and gravel use often involves construction and operation of on-site asphalt batch plants. River run gravel is typically extracted during the summer and fall months during summer low flows. Extraction can be in the form of bar skims, in-channel trenches, or upland (high flood plain) terrace pits and trenches. In some locations, in-channel wetted features such as alcoves are desirable and prescribed for the enhancement of off-channel salmonid habitat or to improve passage into tributaries. Gravel mining in general occurs outside of the wetted channel of larger tributaries and rivers. Exceptions occur where summer bridges are installed to access river bars for extraction. However, summer bridges are designed to avoid direct impact or take of salmonids or other special status species.

In locations where instream gravel mining occurs (e.g., Hoopa Valley), both UKTR spring and fall Chinook Salmon are likely transitory and are unlikely to be directly harmed due to existing regulatory provisions provided by local, state, and federal laws. Some juvenile UKTR spring Chinook Salmon migrate downstream beginning in October, but most remain in the headwaters until spring (Moyle et al. 2008), and therefore have a low likelihood of direct impact or take from gravel extraction methods described above.

6.14 Legacy Mining Impacts

Declines in salmonid populations in the region likely began around the time of the California gold rush, about 1850. Hydraulic mining using pressurized water was commonly used to wash away entire hillsides adjacent to waterways. This caused extreme sediment input and movement that would have strongly affected both adult and juvenile salmonids as well as other aquatic species. Residual effect of this large-scale historical disturbance persists to the present (see Section 6.2).

6.15 Water Diversion

Diversion dam construction, water diversions, and other anthropogenic factors resulted in precipitous declines of UKTR spring Chinook Salmon in the 19th century (Snyder 1931). The large UKTR spring Chinook Salmon run in the Shasta River is thought to have all but disappeared with the construction of Dwinnell Dam in 1926 (Moyle et al. 1995). The dam continues to divert nearly one third of the flow from the Shasta River and block all fish passage (Lestelle 2012). In the mid to late 20th century, UKTR spring Chinook Salmon populations further declined as a result of hydropower dam construction projects including the Trinity and Iron Gate dams. In 1964, historic precipitation led to catastrophic landslides of clear-cut mountainsides contributing millions of cubic yards of sediment in streams and destroying spawning and rearing habitat (Campbell and Moyle 1991). UKTR spring Chinook Salmon had largely been eliminated from much of their former habitats by the 1980’s as the cold, clear water and deep pools that they require were either absent or inaccessible (NMFS 2018).

Water diversions including Young’s Dam, coupled with ground water pumping, is known to dewater Chinook Salmon habitat in the Scott River. Lewiston Dam on the Trinity River diverted most of the Trinity River water to the Sacramento basin and practically eliminated instream flows in the Trinity River prior to implementation of the Trinity River Restoration Plan. In addition, Lewiston Dam blocks Chinook Salmon access to the Trinity headwaters. It is generally recognized that over a century of dam construction and operation, and water diversions from both the Klamath and Trinity Rivers and tributaries, is a leading cause of declines in UKTR spring and fall Chinook Salmon and other salmonids.

7. Influence of Existing Management

7.1 Klamath River Dam Removal

Four hydroelectric dams located on the Klamath River (J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate dams) are slated for removal in 2022 if permits are received on schedule (Figure 7.1). This extensive dam removal project is intended to achieve free-flowing conditions and volitional fish passage to upper portions of the Klamath River basin. Prior to dam building on the Klamath River, UKTR spring Chinook Salmon likely accounted for most of the Upper Klamath basin's natural salmon production (Huntington 2006).

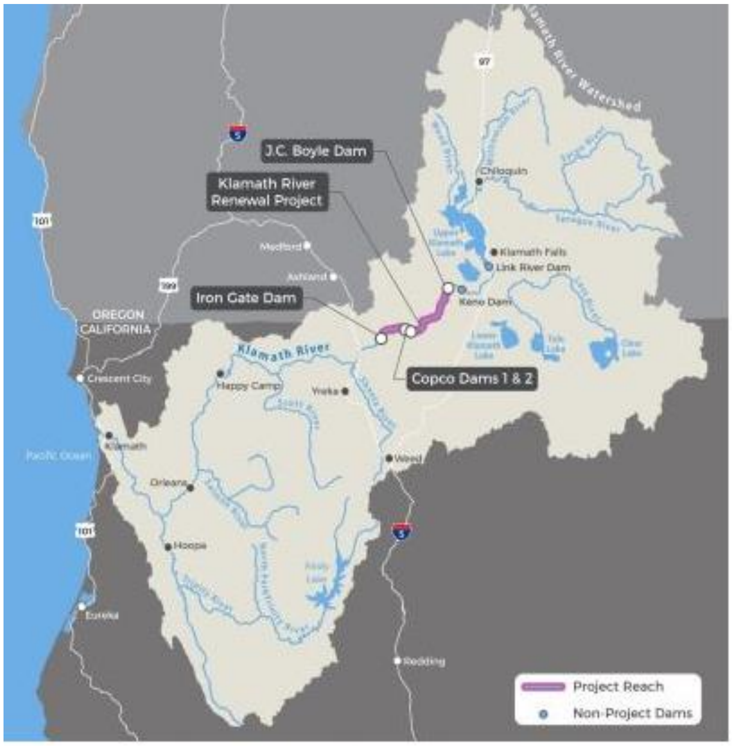

Figure 7.1. Klamath River watershed and development locations.

UKTR spring Chinook Salmon were known to spawn in the tributaries of the Upper Klamath basin (Moyle 2002, Hamilton et al. 2005, Hamilton et al. 2016) with large numbers of UKTR spring Chinook Salmon spawning in the basin upstream of Klamath Lake in the Williamson, Sprague, and Wood rivers (Snyder 1931). The runs in the Upper Klamath basin are thought to have been in substantial decline by the early 1900s and were eliminated by the completion of Copco No. 1 Dam in 1917 (Snyder 1931).

The decline of the Klamath River UKTR spring Chinook Salmon prior to Copco No. 1 Dam has been attributed to dams, overfishing, irrigation, and commercial hydraulic mining (Coots 1962; Snyder 1931). Large-scale mining operations occurred primarily in the late 1800's, and along with overfishing, resulted in diminished UKTR spring Chinook Salmon representation in the basin prior to large dam construction in the early 1900's. Dams have eliminated access to much of the historical UKTR spring Chinook Salmon spawning and rearing habitat and are at least partly responsible for the extirpation of at least seven spring population components from the Klamath-Trinity River system (Myers et al. 1998). For example, the construction of Dwinnell Dam on the Shasta River in 1926 was soon followed by the disappearance of the UKTR spring Chinook Salmon run in that tributary (Moyle et al. 1995).

Currently, UKTR spring Chinook Salmon in the Klamath basin are found mostly in the Salmon and Trinity rivers and in the mainstem Klamath River downstream from these tributaries during migratory periods, although a few fish are occasionally observed in other areas (Stillwater Sciences 2009 and this report). Based on data from 2005-2014 (CDFW 2015), the Salmon River contributions to the overall escapement of UKTR spring Chinook Salmon ranged from 1-12% of the total escapement, and from 1-20% of the natural escapement. To date, no UKTR spring Chinook Salmon spawning has been observed in the mainstem Klamath River (Shaw et al. 1997).

In the short term, dam removal activities will alter suspended sediment concentrations, bedload sediment transport and bedload deposition. Since UKTR spring Chinook Salmon are primarily distributed in the Klamath River downstream of the Salmon River their exposure to temporarily elevated concentrations of suspended sediment that would occur in the mainstem Klamath River due to dam removal would be limited. No impact from suspended sediment is anticipated for all UKTR spring Chinook Salmon spawning and rearing (SWRCB 2018). Suspended sediment is anticipated to have sublethal effects on adult migration, primarily for those adults returning to the Salmon River (around 5% of all spring migrants). All out-migrating Salmon River UKTR spring Chinook Salmon smolts enter the Klamath River far enough downstream from the dam removal project that suspended sediment concentrations are predicted to be much lower than further upstream. Under existing conditions, suspended sediment concentrations can be naturally quite high from tributary contributions of suspended sediment; therefore, sublethal effects on outmigrants are predicted to be similar to existing conditions (SWRCB 2018). Based on no predicted substantial short-term decrease in UKTR spring Chinook Salmon abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to UKTR spring Chinook Salmon in the short term due to the Klamath River dam removal project (SWRCB 2018).

In the long term, removal of the Klamath River dams will increase habitat availability, restore a more natural temperature regime, improve water quality, and reduce the likelihood of fish disease, all of which would be beneficial for UKTR spring Chinook Salmon. Dam removal would restore connectivity to hundreds of kilometers of potentially usable habitat in the Upper Klamath basin, including additional habitat within the reach where the dams are currently situated. Access to additional habitat will provide a long-term benefit to UKTR spring Chinook Salmon (SWRCB 2018). The expansion of habitat-choice opportunities would allow increased expression of life-history variation and the restoration of additional populations of UKTR spring Chinook Salmon with the effect of strengthening resiliency of Chinook Salmon in the Klamath basin, particularly because passage upstream of Iron Gate Dam would provide access to groundwater-fed thermal refugia during summer and fall, as well as providing slightly warmer winter water temperatures that are conducive to growth (Hamilton et al. 2011). By providing an unimpeded migration corridor, the dam removal project will provide the greatest possible fish-passage benefit, resulting in improved survival and reproductive success (Buchanan et al. 2011). As mentioned above, dam removal is predicted to result in warmer water earlier in the spring and early summer and cooler water earlier in the late summer and fall, with diurnal variation more in sync with historical migration and spawning periods in the mainstem upstream of the confluence with the Salmon River (Hamilton et al. 2011). These changes will result in more favorable water temperatures for UKTR spring Chinook Salmon in the mainstem, supporting fish that recolonize habitat upstream of the Salmon River.

Because of their widespread distribution and abundance in the Klamath basin, UKTR fall Chinook Salmon are likely to rapidly colonize suitable areas above the current dam sites when dams are removed.

Although their distribution and abundance in the Klamath River is limited, it is anticipated that dam removal will provide opportunities for the UKTR spring Chinook Salmon to increase in abundance and productivity, improve spatial structure, and create conditions conducive to maximizing and maintain genetic diversity. Implementation of the Klamath Dam Removal Project is predicted to be beneficial for UKTR spring Chinook Salmon in the long term (SWRCB 2018).

7.2 Salmonid Reintroduction Plans

In 1966, the Oregon Department of Fish and Wildlife (ODFW) initiated a study of the feasibility of reintroducing salmonids above barriers in the Klamath drainage (Fortune et al. 1966). As a result of that report, ODFW expressed support for reintroduction when and if above barrier passage became feasible.

The original FERC license for the Klamath Hydropower Project was granted in 1956 and expired in 2006. As a result of an administrative court ruling, relicensing required building and operating fishways to allow anadromous fish above dams. Because relicensing would be contingent upon development of upstream passage, ODFW developed *A Plan for the Reintroduction of*

Anadromous Fish in the Upper Klamath basin (ODFW 2008). This reintroduction plan was added as an amendment to ODFW's Klamath River basin Fish Management Plan. The reintroduction plan proposes two phases 1) development of an implementation plan to guide reintroduction and monitoring, and 2) a conservation plan to establish desired conservation status goals (e.g., escapement goals) for reintroduced populations.

In 2019, ODFW circulated a draft of the phase 1 reintroduction implementation plan for the restored river subsequent to removal of four dams (ODFW & Klamath Tribes 2019). The plan includes proposals for passive reintroduction of steelhead, Coho Salmon, and fall Chinook Salmon. Because UKTR spring Chinook Salmon are present in the Klamath at such small numbers (see *Section 4 Status and Trend*), natural passive reintroduction was judged unlikely to produce results in the desired time. Therefore, the plan proposes active reintroduction of spring Chinook Salmon to the basin. The original plan identifies Rogue River spring Chinook Salmon as the best source population; however, the actual population to be used has not yet been chosen, and other possibilities for a reintroduction source exist, including introducing spring alleles from Trinity River spring Chinook Salmon to Klamath River fall Chinook Salmon in an active conservation hatchery program. No decisions have been made at the time of this report.

The Klamath, Karuk, and Yurok tribes also produced a plan for upper river reintroductions (Huntington et al. 2006). Both reintroduction plans include recommendations for the method of reintroduction (passive, active, or some combination), stock selection, disease issues and management, and competition, restoration and monitoring priorities, and natural resource management strategies with emphasis on water and key species.

7.3 Forestry Activities and Timber Harvest

Currently, many agencies are taking actions to understand the direct and indirect effects of forestry activities on anadromous salmonids, more effectively implement current forest practice rules, and reduce impacts to potential or occupied anadromous habitat. In addition, efforts are underway to restore degraded anadromous habitat, estimate the status of anadromous salmonids in harvested watersheds, and increase anadromous salmonid populations. Along with the California Department of Fish and Wildlife, state agencies addressing timber harvest issues include the California Department of Forestry and Fire Protection (CalFire), California State Board of Forestry and Fire Protection (BOF), the California Regional Water Quality Control boards (RWQCB), and the California Geological Survey (CGSO). The two federal agencies primarily involved in timber harvest and anadromous salmonid issues are the NMFS and the USFS (CDFG 2002).

To further protect listed anadromous salmonids and their habitats, the Anadromous Salmonid Protection (ASP) rules were approved by the State Board of Forestry and Fire Protection (BOF) during their September 2009 meeting held in Sacramento, California. The rules were recently revised under the “Class II-L Identification and Protection Amendments, 2013” rule package approved by the BOF in October 2013.

As explained in the Final Statement of Reasons (FSOR) adopted by the BOF, the ASP rules are intended to protect, maintain, and improve riparian habitats for state and federally listed anadromous salmonid species. These rules are permanent regulations and replace the interim Threatened or Impaired Watershed Rules (T/I Rules) which were originally adopted in July 2000 and readopted six times.

The BOF’s primary objectives in adopting the ASP rules were: (1) to ensure rule adequacy in protecting listed anadromous salmonid species and their habitat, (2) to further opportunities for restoring the species’ habitat, (3) to ensure the rules are based on credible science, and (4) to meet Public Resources Code (PRC) Section 4553 for review and periodic revisions to FPRs. The main goals of the BOF for the rule revisions included having an update based on science, providing a high level of protection for listed species, having rules that contribute to anadromous salmonid habitat restoration, having consistency with partner agency mandates, and promoting landowner equity, flexibility and relief opportunities.

7.4 Commercial and Recreational Fishing

UKTR spring Chinook Salmon are classified as a non-target species by the PFMC (2016). However, both natural- and hatchery-origin UKTR spring Chinook Salmon population components provide minor contribution to ocean fisheries from Cape Falcon, Oregon, to Point Sur, California.

Weak Klamath River salmon stocks resulted in the closure of commercial salmon fishing in 2006 in the Klamath Management Zone on the California coast, and severely curtailed the commercial fishing season along the Oregon coast (USDI et al. 2012). The large spawning salmon fish kill in the Klamath River between 20 – 27 September 2002, may have affected salmon abundance in following years[13]. The federal government declared that year to be a fishery disaster and released $60 million in relief funds to help compensate losses to commercial fishermen and fishing related businesses in Oregon and California (Upton 2011). More recently, as of March 2017, the expected adult return of Klamath fall Chinook Salmon is forecast to be the lowest on record.

In inland waters, there are sportfishing closures above Weitchpec on the Klamath River (Trinity confluence) and on the Lower Trinity River below the South Fork Trinity River. These closures

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[13] However, spawning escapement in 2002 did not go below the established conservation floor and similar reduced abundance was observed in other cohorts that did not experience the fish kill.

were specifically put into place to protect natural-origin UKTR spring Chinook Salmon (W. Sinnen, CDFW, Personal Communication, January 2020)[14].

7.4.1 Ocean Fishery Management

Ocean salmon fisheries are intrinsically based on mixed stocks, meaning that several different ESUs or stocks are combined in the fishery and the origin of any individual harvested cannot be determined at the time of harvest. In mixed-stock fisheries, fishing is not focused on any one stock; however, fishing opportunity is designed to target relatively stronger stocks while protecting lower abundance stocks (i.e., “weak-stock management”). The most constraining stocks to ocean salmon fisheries can vary each year, however, exploitation rates and other harvest controls for ESA-listed Chinook are generally factors. When their abundance is low, UKTR fall Chinook Salmon (KRFC) (and/or Sacramento River fall Chinook Salmon) may also constrain fisheries.

For management planning of ocean fisheries, relatively data-rich Klamath River fall Chinook Salmon (KRFC) are used as the indicator-stock for all Klamath-Trinity basin Chinook Salmon stocks (including the spring ecotype component), as well as several southern Oregon and northern California stocks (e.g., Rogue and Smith rivers) (PFMC 2016, Table 7.1), and as a proxy for data-poor ESA-listed California coastal Chinook Salmon. Fisheries management is conducted at the stock complex level, assuming protections applied to Klamath River fall Chinook Salmon KRFC will similarly protect the other stocks within the complex. UKTR spring Chinook Salmon do not currently have stock-specific management measures, and the effectiveness of existing Klamath River fall Chinook Salmon (KRFC) management objectives to similarly protect them has not been quantitatively evaluated.

Table 7.1. Pacific Fishery Management Council ocean salmon fishery management areas.

Code	City	Location
NORS	Tillamook Newport	Cape Falcon to Florence South Jetty, OR
COS	Coos Bay	Florence S. Jetty to Humbug Mountain, OR
KMZO	Brookings	Humbug Mountain, OR, to OR/CA Border
KMZC	Crescent City	OR/CA Border to Big Lagoon, CA
	Eureka	Big Lagoon to Horse Mountain, CA (Humboldt S. Jetty for commercial fishery)
FTB	Fort Bragg	Horse Mountain to Point Arena, CA
SNF	San Francisco	Point Arena to Pigeon Point, CA
MON	Monterey	South of Pigeon Point, CA

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[14] These closures were in place for many years prior to the Fish and Game Code Section 2084 take allowance put in place during CESA candidacy.

The Pacific Coast Salmon FMP (PFMC 2016), as adopted by the PFMC, details how salmon are to be managed in federal ocean waters consistent with the Magnuson-Stevens Fishery Conservation and Management Act. Key elements of the plan include stock-specific conservation objectives and harvest control rules aimed at limiting harvest to achieve escapement targets. In addition to the Salmon FMP, the Council must also comply with consultation standards that establish harvest rate caps, maximum allowable impact rates, and specific time and area closures for ESA-listed salmon stocks. Together, the Salmon FMP and ESA consultation standards provide a management framework for constructing ocean salmon seasons on an annual basis. This framework is used by the PFMC to develop annual management recommendations that establish escapement objectives, harvest objectives, season dates, harvest quotas, minimum size lengths, and possession and landing restrictions. The NMFS implements the Council's recommendations by setting annual federal salmon fishing regulations. State management of stocks covered by the federal Salmon FMP must remain consistent with FMP conservation objectives, harvest rate caps, and allocation requirements.

One of the challenges in managing mixed stock ocean salmon fisheries is determining appropriate harvest levels for abundant stocks in the presence of less abundant stocks. Salmon stocks that are separated spatially and temporally in their natal rivers migrate to the ocean and intermingle along the coast. These stocks are visually indistinguishable at the time of harvest and as a result, "weak" stocks, such as state and federally listed ESUs, are often incidentally harvested along with more fish from more abundant healthy populations. Available CWT data of hatchery-origin stocks allow fisheries managers to make stock-specific ocean abundance forecasts and evaluate specific time and area fishery impacts. Using the best available science, fisheries managers aim to construct ocean salmon seasons that target abundant stocks, while limiting fishery impacts on stocks of special concern.

7.4.2 Sacramento River Fall Chinook and Klamath River Fall Chinook FMP Harvest Control Rules and Conservation Objectives

Sacramento River (SR) fall Chinook Salmon and UKTR fall Chinook Salmon (KRFC) are typically the most abundant stocks in California's ocean salmon fisheries and make up most of the ocean harvest. Due to their relative abundance, these two stocks are often the targets in California's ocean fisheries and therefore play an important role in the annual fisheries planning process. Management of these stocks is guided by FMP harvest control rules that limit harvest to appropriate levels based on anticipated abundance in order to achieve escapement targets (Figures 7.2, 7.3, 7.4).

SR fall Chinook Salmon and UKTR fall Chinook Salmon (KRFC) harvest control rules operate by setting allowable fishery exploitation rates based on potential spawning fish abundance forecasts absent fishing. Stock-specific biological reference points frame the curve of the harvest control rule and serve as triggers for management actions. Once the number of potential spawning fish is determined, the point of intersection at the curve of the line will determine the maximum allowable fishery exploitation rate expected to achieve the targeted level of spawning fish escapement in a given year. SR fall Chinook Salmon and UKTR fall Chinook Salmon (KRFC) are particularly important in the annual fisheries planning process because these two stocks typically make up the bulk of ocean harvest. When populations of these two target stocks decline, harvest control rules limit fishing by setting caps on fishery exploitation rates and therefore limiting the amount of harvest allowed for each stock.

Depending on the abundance forecast, the harvest control rule will take effect in one of three ways: 1) At higher spawning escapement forecast levels, the harvest control rule establishes a maximum exploitation rate that fisheries may not exceed. 2) At intermediate spawning escapement forecast levels, the harvest control rule establishes an exploitation rate intended to result in producing exactly the number of spawning fish specified in the conservation objective. 3) At lower spawning escapement forecast levels, fishing is still allowed but at much reduced exploitation rates, with the expectation that the conservation objective will not be met (*de minimis* fishing).

The UKTR fall Chinook Salmon (KRFC) harvest control rule with calculated stock-specific biological reference points is displayed in Figure 7.2. “Potential spawner abundance” absent fishing is defined in terms of natural area adult escapement due to availability of age-specific escapement data of natural-origin stocks, which allows for direct abundance forecasting methods. The FMP defined conservation objective for UKTR fall Chinook Salmon (KRFC) is set at 40,700 natural area adult spawning fish, which is the annual spawning adult escapement level determined to be optimum for producing the maximum sustainable yield (S_{MSY}) over the long-term. When the number of forecasted spawning fish, pre-fishery, ranges between 54,300 and 127,200 natural-area adults, the harvest control rule yields an exploitation rate that will produce, in expectation, the number of spawning fish defined in the FMP conservation objective (S_{MSY} or 40,700 natural area adults). Forecasted abundance of spawning fish above this range yields the maximum allowable exploitation rate of 68% while values below this range yield exploitation rates that require *de minimis* levels of fishing.

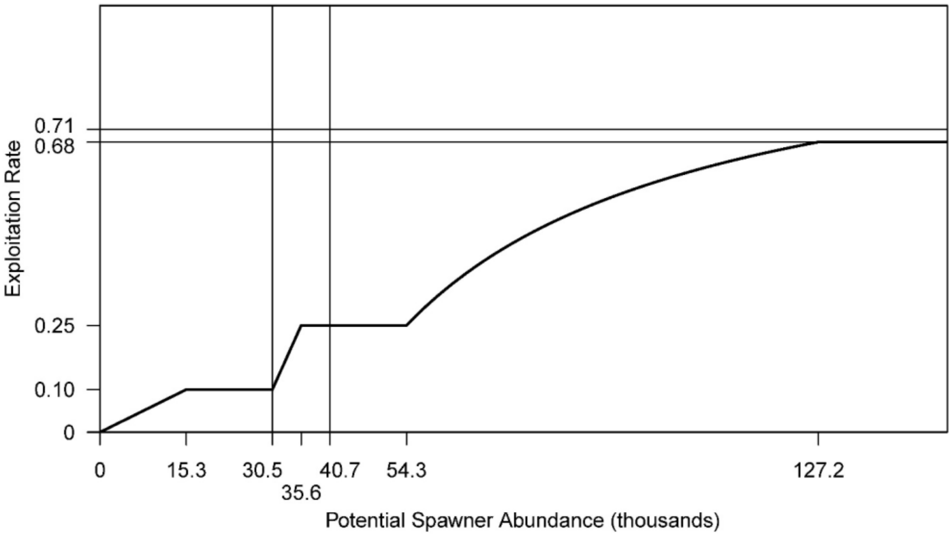

Figure 7.2. The Klamath River fall Chinook Salmon (KRFC) control rule. Potential Spawner Abundance is the predicted number of natural area adults returning to spawn, in the absence of fisheries.

The Sacramento River fall-run Chinook Salmon harvest control rule with calculated stock-specific biological reference points is displayed in Figure 7.3. The absence of age-specific escapement data for natural-origin spawning adults precludes direct abundance forecasting methods like those used for UKTR fall Chinook Salmon (KRFC), so an estimate for abundance known as the Sacramento Index (SI) is used to estimate potential spawning fish abundance. The SI is the sum of adult Sacramento River fall-run Chinook Salmon ocean harvest, river harvest, and hatchery and natural area spawning escapement. The annual SI forecast is generated using a model that relates jack escapement to SI abundance for past years to produce an estimate of hatchery and natural area adult spawning fish in the absence of fisheries. The FMP defined conservation objective for Sacramento River fall-run Chinook Salmon is 122,000 – 180,000 combined hatchery and natural area adult spawning fish, which is the range of escapement determined to be optimum for producing the maximum sustainable yield for the Central Valley fall Chinook stock complex (S_{MSY}). When the SI forecast ranges between 162,700 and 406,700 pre-fishery natural-area and hatchery adults, the harvest control rule yields an exploitation rate that will produce, in expectation, the minimum number of spawning fish defined in the FMP conservation objective (S_{MSY} or 122,000 hatchery and natural area spawning fish). An SI forecast above this range yields the maximum allowable exploitation rate of 70%, while values below this range yields exploitation rates that allow only *de minimis* levels of fishing.

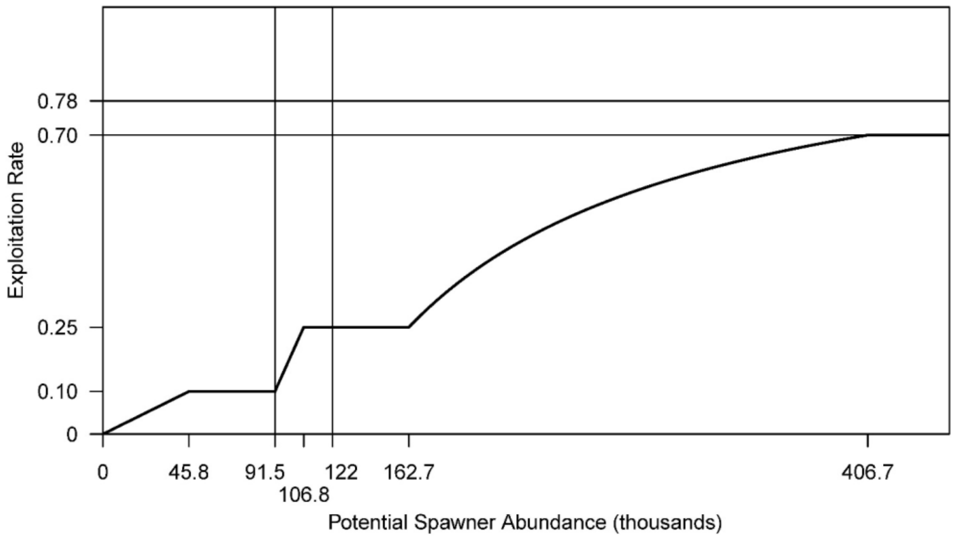

Figure 7.3. Sacramento River fall Chinook Salmon control rule. Potential Spawner Abundance is the predicted number of hatchery and natural area adults returning to spawn, which is equivalent to the Sacramento Index (SI).

7.4.3 Fishery Status Determination Criteria

The PFMC's Salmon FMP outlines specific criteria for determining whether a salmon stock has been subject to overfishing, is approaching an overfished condition, or is overfished. A stock is considered to have been subject to overfishing when the postseason estimate of the fishing mortality rate exceeds the maximum fishing mortality threshold in any single year. A stock is considered to be approaching an overfished condition when the geometric mean of the two most recent postseason escapement estimates, and the current preseason escapement forecast is below the minimum stock size threshold (MSST). An overfished status determination is made when the geometric mean of the three most recent postseason escapement estimates is below the MSST. When a stock is declared overfished, the PFMC is required to direct the development a rebuilding plan which outlines contributing factors to the stock's decline, evaluates management tools, and recommends actions to achieve a rebuilt status of the stock.

7.4.4 Sacramento River winter Chinook ESA Consultation Standard

ESA- and CESA-listed endangered Sacramento River (SR) winter Chinook Salmon are harvested incidentally in ocean fisheries, primarily in the San Francisco and Monterey management areas south of Point Arena. A two-part consultation standard is used as part of the annual management process to limit fishery impacts to this stock. The SR winter Chinook Salmon ESA consultation standard plays an important role in the annual fisheries planning process, as it often restricts fishing opportunity south of Point Arena, particularly in the sport fishery.

The first component of the SR winter Chinook Salmon consultation standard consists of specific fishery closures and size limit provisions in times and areas where SR winter Chinook Salmon are most likely to be encountered. Recreational fisheries in the San Francisco management area, located between Point Arena and Pigeon Point, shall open no earlier than the first Saturday in April and close no later than the second Sunday in November. Recreational fisheries in the Monterey management area, located between Pigeon Point and the U.S./Mexico Border, shall open no earlier than the first Saturday in April and close no later than the first Sunday in October. The minimum size limit must be at least 20 inches total length. The commercial salmon fishery between Point Arena and the U.S. – Mexico border shall open no earlier than 1 May and close no later than 30 September, with the exception of an October fishery conducted Monday through Friday between Point Reyes and Point San Pedro, which shall end no later than 15 October. The minimum size limit must be at least 26 inches total length.

The second component of the SR winter Chinook Salmon consultation standard is a control rule that specifies the maximum allowable impact rate based on a forecast of the age-3 escapement absent fishing (Figure 7.5). When the age-3 escapement absent fishing is forecasted to be 3,000 or more, the maximum forecast age-3 impact rate is 0.20. Between age-3 escapement absent fishing levels of 3,000 – 500, the maximum forecast age-3 impact rate decreases linearly from 0.20 – 0.10. At age-3 escapement absent fishing levels less than 500, the maximum forecast age-3 impact rate decreases linearly from 0.10 – zero.

7.4.5 California Coastal Chinook Salmon ESA Consultation Standard

The California coastal Chinook Salmon ESU is listed as threatened under the ESA and comprises all Chinook Salmon populations spawning in coastal rivers between Redwood Creek south to the Russian River. The lack of ocean harvest and spawning escapement data for this natural-origin stock prohibited the development of an abundance-based management strategy and necessitated the use of the fall Chinook Salmon (KRFC) proxy. The NMFS ESA consultation standard for California coastal Chinook Salmon restricts the KRFC age-4 ocean harvest rate to no more than 16.0%. By setting an ocean harvest rate cap on age-4 KRFC, this consultation standard serves to protect California coastal Chinook Salmon by limiting harvest and fishery impacts to times and areas where encounters with this stock are most likely to occur. This consultation standard is often a constraining factor in the annual fisheries planning process and results in reduced harvest and fishing opportunity in the Fort Bragg management area and the Klamath Management Zone.

7.4.6 Existing Regulatory Protection in Relation to Ocean Distribution

Ocean distribution based on analysis of CWT recoveries in ocean fisheries suggest that ocean distribution of UKTR spring and fall Chinook Salmon are similar (see Section 2.4). UKTR spring Chinook Salmon may extend to more northern catch areas and ocean presence is seasonal due to different migration timing. Because geographic distribution of the spring and fall ecotypes overlaps over much of the California and Oregon Coast, and because the harvest index of TRH produced UKTR spring Chinook Salmon is lower than UKTR fall Chinook Salmon (KRFC) in most areas, it is reasonable to infer that the UKTR fall Chinook Salmon (KRFC) harvest control rule and the California coastal Chinook Salmon ESU harvest rate proxy similarly protects UKTR spring Chinook Salmon overall. However, time-area combinations where the TRH UKTR spring Chinook Salmon harvest index exceeds the UKTR fall Chinook Salmon (KRFC) harvest index may warrant further scrutiny.

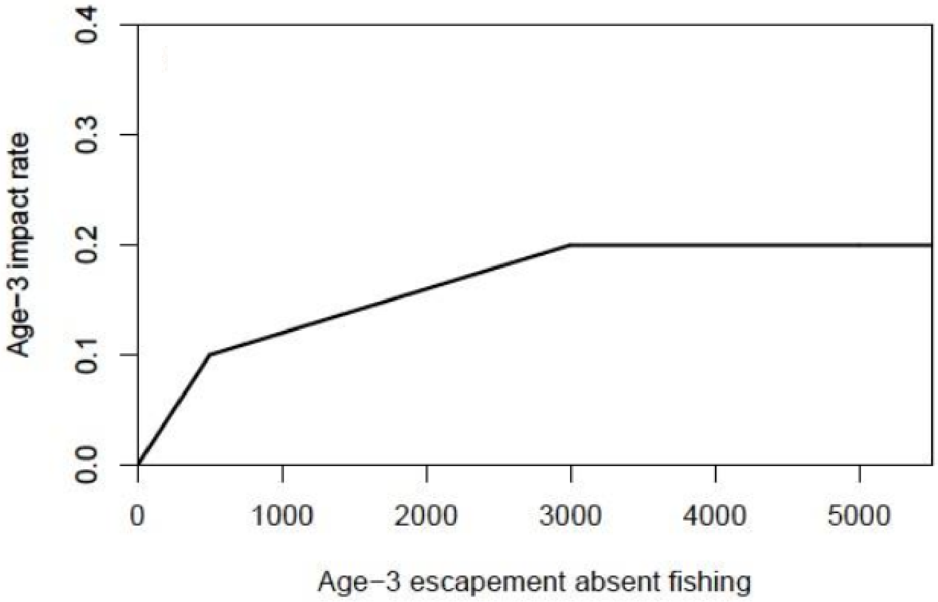

Figure 7.4. Sacramento River winter Chinook Salmon impact rate control rule. The maximum forecast age-3 impact rate for the area south of Point Arena, California, is determined by the forecasted age-3 escapement in the absence of fishing.

7.4.7 River Mouth Closures

Existing state and federal salmon fishing regulations set annual river mouth closures to protect salmon as they congregate outside their natal rivers and prepare for their inland migration. California regulates set closure areas centered on the mouths of the Klamath, Smith, and Eel rivers which prohibit commercial and recreational fishing during certain times of the year. Federal regulations prohibit commercial salmon fishing year-round in the Klamath Control Zone, an area of 12 square nautical miles centered around the Klamath River mouth, as well as in the area of coastline between the Humboldt South Jetty and Horse Mountain. These closures serve as a powerful management measure by protecting sensitive times and areas where certain stocks, which were once widely dispersed throughout the mixed-stock ocean fishery, become more concentrated and are more easily susceptible to fishing.

7.4.8 Additional Protective Measures

The Salmon FMP and ESA consultation standards work together to provide a management framework by defining conservation objectives, harvest control rules, and by setting caps on ocean harvest rates and impact rates. However, the PFMC has the responsibility to consider additional external factors that may affect abundance as part of the annual management process. These factors may include critically low escapement numbers for natural area spawning fish, poor indicators for marine and freshwater environmental conditions such as El Niño cycles and drought, and stock status determinations such as stocks in an overfished or approaching overfished condition. Given the specific current year circumstances, the PFMC may determine that additional conservative measures beyond those outlined in the Salmon FMP and ESA consultation standards are necessary to limit harvest and fishing opportunity on certain stocks.

As an example, fishing seasons have been restricted beyond minimum conservation objectives in recent years due to the overfished status determination for SR fall Chinook Salmon and UKTR fall Chinook Salmon, the main stocks supporting California's ocean fisheries. The state's most recent drought combined with poor ocean conditions led to three consecutive years of low escapement of spawning adults, resulting in both stocks being classified as overfished in 2017. During the 2018 and 2019 fisheries planning process, the PFMC designed ocean salmon fisheries to result in higher numbers of returning spawning fish for SR fall Chinook Salmon, beyond the minimum requirements of the FMP conservation objectives. This decision resulted in lost fishing opportunity and reduced harvest in hopes of expediting the rebuilding process.

Together, FMP guidelines and ESA consultation standards have a confounding effect on limiting harvest across the California coast. Management objectives can act independently to limit fishery impacts to specific stocks in particular times and areas or can be additive to provide protections for many stocks across time and space. Because weak stocks and abundant stocks are intermingled in the mixed-stock ocean fishery, fishery restrictions can provide umbrella protections for multiple stocks of salmon during the marine portion of their life cycle, and by extension, protection of UKTR spring Chinook Salmon.

7.5 Disease

In the Klamath River, a valuable management tool for the prevention of disease in Chinook Salmon is the use of special flow releases from reservoirs. Conditions conducive to ich and columnaris outbreaks, as occurred in 2002, are usually seen in late summer and early fall, when water temperatures tend to be high and water flows low. Low water flows and high water temperatures can impede fish passage and cause fish to congregate at high density. Low water flows also concentrate pathogens, while increased temperatures may increase pathogen reproduction rates. Higher densities of fish and pathogens increase the likelihood of pathogens contacting susceptible fish hosts. Increasing water releases from upstream reservoirs flush out pathogens before they contact susceptible fish and promotes upstream spawning fish migration, spreading susceptible host fish more widely through the river system (Strange 2012).

In 2017 the U.S. Department of the Interior released a “Record of Decision” (ROD) enacting a “Long-Term Plan to Protect Adult Salmon in the Lower Klamath River.” The decision allows releases of stored Trinity River water to ameliorate high stream temperature and low flows in the Lower Klamath River during late summer. High stream temperature and low flows were principle environmental conditions thought to have caused a severe outbreak of ich and columnaris that lead to the historic lower Klamath fish kill in 2002. The ROD is predicated on adaptive management and real time monitoring of flow, temperature, fish densities and pathogen levels.

Special release flows may also be useful to alleviate the effects of the pathogen *Ceratonova shasta*. *C. shasta* has a complex life cycle requiring a polychaete worm intermediate host. The intermediate host releases actinospores which are infective to fish. Decomposition of infected fish releases myxospores, which infect the polychaete intermediate host. The intermediate host tends to proliferate in areas of high sediment and nutrient deposition. Large water releases that provide a sediment scouring effect may help control infected polychaete populations through the removal of sediment. Increased spring flows may also provide for actinospore dilution and disruption, resulting in lower infection rates of out-migrating juvenile salmon. Fall water pulses result in myxospore redistribution and stranding, and possibly carcass stranding, which may result in lower numbers of infective myxospores reaching the intermediate host worms (Hillemeier 2017).

Other management strategies to decrease disease include prohibiting transportation between drainages, or importation, of infected, diseased, or parasitized fish. Regular health monitoring of hatchery production fish is currently performed to detect disease. Chemotherapeutics and antibiotics may be used to control external parasites and bacteria, and systemic bacterial infections. Best management practices should be used to avoid infectious agents and stressful conditions. Monitoring of hatchery broodstock for bacterial kidney disease (BKD), by fluorescent antibody testing of ovarian fluid, is helpful to reduce the incidence of this disease in Klamath-Trinity hatcheries.

7.6 Fisheries and Habitat Restoration and Management Plans

This section lists existing and/or historical restoration and management plans focused on or applicable to restoration or recovery of UKTR spring and fall Chinook Salmon in the Klamath basin.

7.6.1 Fish and Fish Habitat Restoration Plans:

Action Plan for Restoration of the South Fork Trinity River Watershed – A 1994 plan for adaptive management and restoration of anadromous fish populations in the South Fork Trinity River. http://www.krisweb.com/biblio/sft_usbor_pwa_1994_sftplan/pwa1.htm

Klamath basin Integrated Fisheries Restoration and Monitoring – An in-development adaptive management framework for planning the restoration and recovery of native fish species in the Klamath basin while improving flows, water quality, habitat, and ecosystem processes. http://kbifrm.psmfc.org/

Klamath Dam Decommissioning and Removal Project – A plan for decommissioning and removal of four hydroelectric dams on the mainstem Klamath River. Dam removal is scheduled to begin in 2022. https://www.waterboards.ca.gov/waterrights/water_issues/programs/water_quality_cert/lower_klamath_ferc14803.html

Klamath Tribes Wetland and Aquatic Resources Program Plan – Describes developing a program to reintroduce endangered suckers and Chinook Salmon to historic spawning locations in the Upper Klamath sub-basin. https://www.epa.gov/sites/production/files/2015-10/documents/tkt_final_warpp.pdf

Long Range Plan for the Klamath River basin Conservation Area Fishery Restoration Program – Developed in 1991 by the defunct Klamath River Basin Fisheries Task Force, this adaptive management plan was intended to develop policies that would help restore anadromous fish in the Klamath basin. http://www.krisweb.com/biblio/gen_usfws_kierassoc_1991_lrp.pdf

Reintroduction of Anadromous Fish in the Upper Klamath basin – A 2008 plan by the Oregon Department of Fish and Wildlife to modify their existing basin fishery plans to include reintroduction of anadromous fish, including UKTR spring Chinook Salmon, to the Upper Klamath sub-basin. https://nrimp.dfw.state.or.us/nrimp/information/docs/fishreports/Klamath%20Reintroduction%20Plan_Final_Commission%20Adopted%202008.pdf

Salmon River Floodplain and Mine Tailing Habitat Restoration and Enhancement Plan – A 2018 technical memo by Stillwater Sciences evaluated opportunities and constraints for restoring floodplain and fluvial processes in the Salmon River. https://srrc.org/publications/programs/habitatrestoration/Salmon%20River%20Floodplain%20Enhancement%20Tech%20Memo_Final%202018.pdf

Salmon River Sub-basin Restoration Strategy: Steps to Recovery and Conservation of Aquatic Resources – A 2002 strategic plan for targeting collaborative restoration and protection efforts to restore the biological, geologic, and hydrogeologic processes that shape the quality of aquatic habitat. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5110056.pdf

Trinity River Restoration Program – Founded to address concerns over the impact of Central Valley Project activities on the mainstem Trinity River and its fish, the Trinity River Restoration Program is intended to manage sediment, restore watershed processes, improve infrastructure, and monitor and manage the river adaptively. https://www.trrp.net/program-structure/background/rod/

7.6.2 Land/Water Use and Water Quality Management Plans:

Klamath Basin Monitoring Program – This program implements, coordinates, and collaborates on water quality monitoring and research throughout the Klamath basin. http://www.kbmp.net/

Klamath Basin Restoration Program – A partnership between the U.S. Department of the Interior and the National Fish and Wildlife Federation to support basin-wide restoration projects to benefit fish. https://www.nfwf.org/programs/klamath-basin-restoration-program?activeTab=tab-1

Klamath Forest Plan – This document describes the U.S. Forest Service's plan for managing the Klamath National Forests, which occupy a considerable percentage of land in the Klamath basin. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5333197.pdf

Salmon River TMDL and Implementation Plan – This is a plan to address and mitigate temperature issues in the Salmon River Watershed, consistent with the federal Clean Water Act. https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/Salmon_river/

Scott River Watershed Restoration Strategy and Schedule – This document is an assessment and plan for riparian protection, enhancement, and restoration in the Scott River watershed, developed for the Scott River Watershed Council and the Siskiyou RCD. https://a87cd223-4955-4835-9ecf-57ed24f1aaaa.filesusr.com/ugd/87211c_aa57af3fdf4445afa6f21109dcccac36.pdf

Western Klamath Restoration Partnership: A Plan for Restoring Fire Adapted Landscapes – This is a planning effort to guide collaborative fire management in the Western Klamath landscape.

http://karuk.us/images/docs/dnr/2014%20Western%20Klamath%20Restoration%20Partnership_Restoration%20Plan_DRAFT_FINA%20%20%20.pdf

7.6.3 Plans for Other Species That May Also Benefit UKTR Spring and Fall Chinook Salmon:

Fisheries Management Plan (FMP) and Amendments: Fisheries Management and Rebuilding Plans for the Pacific Fishery Management Council – This is the plan for managing ocean fisheries, including monitoring and limits to protect stocks. UKTR spring Chinook Salmon are a non-target stock for PFMC fisheries, but they are likely affected by protections for fall run. https://www.pcouncil.org/Salmon/fishery-management-plan/adoptedapproved-amendments/

Klamath River Fall Chinook Rebuilding Plan https://www.pcouncil.org/wp-content/uploads/2019/08/1_KRFC-RP_Final_070319.pdf

Recovery Strategy for California Coho Salmon – Document to guide the process of recovering Coho Salmon on the north and central coasts of California, including the Klamath basin. https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=99401&inline

Southern Oregon and Northern California Coasts (SONCC) Salmon Recovery Plan – Developed to guide implementation of prioritized actions needed to conserve and recovery of the Southern Oregon/Northern California coast Coho Salmon ESU. www.westcoast.fisheries.noaa.gov/protected_species/Salmon_steelhead/recovery_planning_and_implementation/southern_oregon_northern_california_coast/SONCC_recovery_plan.html

7.7 Gravel Extraction

In 1991, the California Department of Conservation’s Division of Mine Reclamation (DMR) was created to provide a measure of oversight for local governments as they administer the Surface Mining and Reclamation Act (SMARA) of 1975 throughout California. Local Lead Agencies, such as counties administer SMARA with oversight from DMR and their Lead Agency Review and Assistance Program through vetted reclamation plans, annual mine inspections, review of financial assurance cost estimates and uniform application of mining laws and regulations. Reclamation plans are further subject to the California Environmental Quality Act and local land use code; Clean Water Act Section 401 (State Certification of Water Quality) and Section 404 (U.S. Army Corp of Engineers) that regulate the discharge of dredged or fill material into the waters of the United States. Instream gravel mining is subject to, and projects could be authorized by a Lake or Streambed Alteration Agreement (Fish and Game Code Section 1600 *et seq*.). Consultation with the NMFS and/or the Department pursuant to State and Federal ESA may also be warranted. As described, contemporary gravel mining is a highly regulated activity subject to multiple jurisdictions, but methodologies do vary by county and are based on site-specific conditions.

7.8 Suction Dredging

Suction dredging traditionally entails the use of a gasoline powered pump mounted onshore or on a floating platform that excavates (via suction) streambed material (rock, gravel, sand and fine sediment) into a sluice box or across a settling table where gold concentrates and settles out by gravity, then discharges gravel and water back into the stream as unconsolidated tailings. The dredging equipment is often positioned over the extraction area by securing the platform to rock or riparian trees with ropes or cables. A diver typically operates the flexible intake hose (3-12-inch diameter) over a portion of the stream bottom, excavating to a depth of two meters or more, and disturbance areas can range between a few small excavations to the entire wetted area in a section of a stream, including the banks (Harvey and Lisle 1998). Large suction dredges have the capacity to excavate as much as several cubic yards of gravel from the river bottom, depending on the type of streambed material and the operator (Horizon Water and Environment 2012). Current statutory definitions in California are much broader than traditional suction dredging. (See Fish & Game Code, § 5653, subd. (g); Wat. Code, Section 13172.5, subd. (a).)

Suction dredging has been shown to be detrimental to both biotic (Horizon Water and Environment 2012; Griffith and Andrews 1981; Thomas 1985; Harvey 1986) and abiotic stream process (Horizon Water and Environment 2012; Harvey and Lisle 1998) and the severity of the impact can be widespread and, in some cases such as streambanks, lasting. Suction dredging is common during the summer months in many river systems in western North America (Harvey and Lisle 1998). In some streams, salmonids do not emerge from the substrate until summer, and non-salmonids have protracted spawning periods extending into summer (Moyle 1976). UKTR spring Chinook Salmon enter the Klamath River between March and July and spawn between late August and September (Myers at al. 1998), at the peak of low flow and height of summer temperatures. For this reason, impacts to UKTR spring Chinook Salmon may be greater than to UKTR fall Chinook Salmon. In locations such as the Salmon River where UKTR spring Chinook Salmon persist in small numbers, suction dredging would likely entrain and cause mortality of early life stages such as incubating embryos and juvenile fish (Harvey and Lisle 1998).

Suction dredging and in-water mining generally is subject to regulation by both the federal government and the State of California, including on federal land. Suction dredging and in-water mining is subject to regulation by the federal government pursuant to the U.S. General Mining Law of 1872, and the federal Clean Water and Endangered Species Acts, among other federal laws. Suction dredging as defined by state law is subject to regulation in California under the Fish and Game and Water Codes. (See, e.g., Wat. Code, § 13172.5.) State law administered by the Department prohibits the use of vacuum and suction dredge equipment in California rivers, lakes, and streams, except as authorized by permit issued by the Department pursuant to Fish and Game Code Section 5653. The Department administers its related permitting program pursuant to regulations implementing Section 5653. (Cal. Code Regs., tit.

14, §§ 228, 228.5.) Notwithstanding Section 5653 and the Department's related regulations, the use of vacuum or suction dredge equipment, again as defined by state law, has been prohibited as a temporary matter by separate statute since August 2009. (Fish & Game Code, § 5653.1, subd. (b).) Legislation enacted by the State of California in 2015 amending Fish and Game Code Section 5653 and adding Section 13172.5 to the Water Code created a path for the 2009 interim moratorium to lift with additional regulatory and permitting actions by the Department and the State Water Resources Control Board (SWRCB), respectively. (See Stats. 2015, ch. 680 (Sen. Bill 637, Allen), §§ 2-3.) Under the legislation, however, the Department may not issue any permits under Fish and Game Code section 5653 until SWRCB or an appropriate Regional Water Quality Control Board completes a related water quality permitting effort, which is underway but not yet final. (*Id.*, § 5653, subd. (b)(1).) Under current state law, accordingly, the use of vacuum or suction dredge equipment is unlawful in California rivers, streams, and lakes, and any such activity is subject to enforcement and prosecution as a criminal misdemeanor. (See generally Fish & Game Code, §§ 5653, 5653.1, 12000, subd. (a).)

7.9 Habitat Restoration and Watershed Management

Early habitat monitoring in the Klamath basin dates to the early 20th Century (ESSA 2017). These early efforts were fragmented and focused on specific local issues and did not always monitor habitat in relation to fish. However, as fish populations have declined, monitoring efforts have become more coordinated and focused on known stressors.

Early habitat restoration in the Klamath-Trinity basin focused on instream structure whereas more recent work addresses fundamental causes of watershed impairment. Although some efforts still focus on one target species (e.g., certain anadromous salmonids), most restoration projects now aim to improve overall health of the watershed. Kier and Associates (1999) note that gradual progress has been made towards improving watershed function.

Federal, state and local agencies involved in substantial habitat restoration projects in the basin include: National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), the U.S. Forest Service, Natural Resource Conservation Service (part of the U.S. Department of Agriculture), Bureau of Reclamation, and the U.S. Environmental Protection Agency (USEPA), Oregon Department of Fish and Wildlife (ODFW), Oregon Department of Environmental Quality (ODEQ), the California Department of Fish and Wildlife, the California State Wildlife Conservation Board, and the California North Coast Regional Water Quality Control Board (NCRWQCB). Agencies administer restoration grant programs (e.g., Fisheries Restoration Grants Program, NMFS and the Department). Tribal governments also develop and carry out fish habitat and water quality restoration plans for tribal lands.

Restoration work in the region fall into the following categories: fish passage, screening, hatcheries, instream flow restoration, instream habitat restoration, riparian habitat restoration, upland habitat and sediment management, water quality restoration (including nutrient in-flow reduction) and wetland restoration. The number of grant-driven restoration projects examined in ESSA (2017) declined in the last decade; however, spending has increased, suggesting a shift towards fewer but more intensive restoration projects.

The distribution of different restoration projects varies over the basin. Activities associated with fish passage improvement and hatcheries are most commonly found in sub-basins below dams. These projects provide benefits to anadromous fish and are concentrated in the Lower Klamath basin. Instream flow monitoring, instream habitat improvement, riparian restoration, and sediment reduction that watershed-level benefits to a range of aquatic and terrestrial species are distributed more evenly across all sub-basins. A large concentration of riparian restoration projects is also found in the Upper Klamath River.

Projects focused on reducing sediment inputs through management of uplands and roads and riparian restoration projects receive the most funding (ESSA 2017). The largest proportion of total restoration spending and projects have been in the lower Klamath and mid/upper Klamath sub-basin where anadromous fish still have access and existing dams strongly impact habitat quality and quantity.

7.10 Research and Monitoring Programs

Research and monitoring programs in the Klamath basin are in place to support fishery management and recovery of listed and sensitive species. Management is based on ESA and CESA provisions and regulatory actions and funding for restoration focus on ESA-listed species, Species of Special Concern, and fisheries. Management for ESA-listed suckers and Coho Salmon are important elements of the Klamath Irrigation Project operations and Iron Gate Dam operations under the NMFS 2013 Biological Opinion. Many of the recovery plans for species in the basin include adaptive management of recovering populations as an explicit objective, while some recovery plans have a secondary goal of restoring harvest opportunities (ESSA 2017).

The Klamath basin is large and monitoring aquatic species across the entire basin is complex. More than 32 organizations conduct monitoring in 12 Klamath sub-basins. Fish restoration in the Klamath basin has recently shifted from many disconnected projects to a more unified approach. A collaborative group was assembled in the process of developing the Klamath Basin Restoration Agreement and the Klamath Hydroelectric Settlement Agreement. The Klamath Basin Monitoring Program took steps toward a basin-wide monitoring plan. Although existing monitoring is substantial, development of large-scale coordinated monitoring plans with standardized methods that include random/spatially balanced sampling and coordinated reporting would greatly improve the usefulness of monitoring data in the basin.

Within the Klamath basin, there are at least 15 major programs to monitor habitat (including water quality), 14 to monitor fish populations, and nine to monitor the effectiveness of restoration projects. A recent review (ESSA 2017) found that most monitoring is focused on habitat status and trend, followed by population monitoring. Monitoring the effectiveness of restoration projects is less common.

8. Summary of Listing Factors

8.1 UKTR Spring Chinook Salmon as a Separate ESU

The petitioners assert that new information on the association of a specific chromosome region with run timing in UKTR spring Chinook Salmon is enough to classify them as distinct from UKTR fall Chinook Salmon and from the combined UKTR Chinook Salmon ESU. This status review finds that the referenced genomic association (see petition and Prince et al. 2017) with early migration timing is a significant distinguishing feature of the two (spring and fall) ecotypes. However, the Department judges that this novel genomic association, while illuminating an allele at a specific gene region for early migration, is not necessary to demonstrate differences between UKTR spring and fall Chinook Salmon under CESA. Other well-established ecological, life-history, and behavioral differences between UKTR spring and fall Chinook Salmon are sufficient to define them as "different" at some level. The Department has traditionally managed the UKTR spring and fall Chinook Salmon ecotypes differently, with more protections for UKTR spring Chinook Salmon (e.g., inland fishing regulations, placement on the California Species of Special Concern). Regardless of our judgement that there are differences between UKTR spring and fall Chinook Salmon, the Department agrees with other analyses (e.g., Myers et al. 1998; Williams et al. 2011, 2013) that the distinction between UKTR spring and fall Chinook Salmon is most appropriately placed at the level of ecotypes, and that the two combined ecotypes form an interbreeding ESU.

Commented [SN103]: This is a critical component of the decision, that management to conserve both ecotypes is ongoing with additional protections for spring Chinook

UKTR spring Chinook Salmon are not currently considered a DPS or ESU under federal guidelines. Although UKTR spring Chinook Salmon are qualitatively different in some ways from UKTR fall Chinook Salmon, warranting the label of ecotype, they are not reproductively isolated from fall Chinook Salmon and mix with them on spawning grounds. UKTR spring and fall Chinook Salmon ocean distribution also overlaps substantially. However, it has been long recognized that ecotypes spawned in hatcheries as either fall or spring ecotypes are not likely to produce offspring of the opposing ecotype (e.g., Myers et al. 1998).

Commented [AC104]: Changes made by Shawn Narum

The *GREB1L* gene region has been shown to contain elements strongly associated with early migration timing in UKTR Chinook Salmon. UKTR spring and fall Chinook Salmon, and importantly, other Chinook Salmon in California and elsewhere (Anderson and Garza 2019; Narum et al. 2018) possess different forms of this gene region. Homozygotes for the "spring" allele at this gene region are associated with early migration timing (Prince et al. 2017). Heterozygotes are present in the Klamath-Trinity system; however, heterozygotes may not be present in large proportions in all parts of the system, perhaps especially in the Klamath River and tributaries, and individuals with spring run timing may be selected against under current conditions. Selection is likely against early arrival and holding that are characteristic of the UKTR spring Chinook Salmon ecotype. Heterozygotes likely act as a reservoir of "spring" alleles, albeit at low frequency.

Commented [AC105]: Changes made by Shawn Narum

Commented [AC106]: Changes made by Shawn Narum

8.2 Summary of Listing Factors

CESA directs the Department to prepare this report regarding the status of UKTR spring Chinook Salmon based upon the best scientific information available to the Department.

CESA's implementing regulations identify key factors that are relevant to the Department's analyses. Specifically, a "species shall be listed as endangered or threatened ... if the Commission determines that its continued existence is in serious danger or is threatened by any one or any combination of the following factors: present or threatened modification or destruction of its habitat, overexploitation, predation, competition, disease, or other natural occurrences or human-related activities (Cal. Code Regs., tit. 14, § 670.1, subd. (i)(1)(A).

The petitioners assert that the UKTR spring Chinook Salmon is a distinct ESU and is in danger of extinction due to:

- present or threatened modification of its habitat;
- disease; and
- other natural events or human related activities.

The following summarizes the Department's determination regarding the factors to be considered by the Commission in making its decision on whether to list UKTR spring Chinook Salmon as a distinct ESU. This summary is based on the best available scientific information, as presented in the foregoing sections of this status review. Because the best scientific evidence shows that UKTR spring Chinook Salmon are an ecotype of the larger UKTR Chinook Salmon ESU (spring and fall), this status review considers listing factors in relation to the combined ESU.

Commented [MS107]: I disagree with this statement. There is substantial scientific support for considering spring Chinook as an ESU separate from fall Chinook. If they were considered their own ESU, how would these conclusions be modified? Would the Department concur with previous independent assessments summarized in Section 1.5.3?

This status review concludes the following:

1. The best available science does not support the UKTR spring Chinook Salmon as its own ESU separate from the currently defined UKTR Chinook Salmon ESU comprising both spring and fall ecotypes.
2.

   Present or threatened modification or destruction of habitat: Dam construction and other habitat modifications (e.g., historical mining, land and water use) in the Klamath basin have resulted in truncated and fragmented distribution of the UKTR Chinook Salmon ESU in comparison to historical times. The UKTR spring Chinook Salmon ecotype was likely more common and more widely distributed within the basin historically due to conditions that favored expression of the early returning phenotype. Although current distribution of the spring ecotype is fragmented and abundance is low, distribution and abundance of the UKTR Chinook Salmon ESU as a whole is not. The UKTR spring Chinook Salmon ecotype is currently found in small to moderately large numbers in the basin, with notable spawning aggregations in three disjunct locations—

Salmon River on the Klamath, Upper Trinity River, and South Fork Trinity River. UKTR spring Chinook Salmon in the Salmon River and the South Fork Trinity River are less abundant than in the Upper Trinity River. In comparison, UKTR fall Chinook Salmon (and therefore the UKTR Chinook ESU as a whole) are widely distributed in the basin in relatively large numbers.

Four Klamath River dams are planned for removal starting in 2022 if permits are received on schedule. Removal of these dams will allow anadromous fish access to previously blocked spawning and rearing areas upstream into Oregon. The UKTR Chinook ESU, especially UKTR fall Chinook Salmon, abundant in the Klamath River, are expected to benefit from access to this expanded upstream habitat. However, UKTR spring Chinook Salmon, whose only consistent current representation in the Klamath River is in the Salmon River, likely do not exist in high enough numbers and are too far down in the drainage to expect them to rapidly naturally repopulate the Upper Klamath. The Department does not know with any certainty whether or how the spring ecotype will naturally respond to dam removal. At the same time, the Department believes that recovery potential for UKTR spring Chinook Salmon and other anadromous fish is much more likely without the dams.

Although habitat alteration in the basin has been extensive, the UKTR Chinook Salmon ESU remains widely distributed and in large numbers. Therefore, the Department does not consider the continued existence of the UKTR Chinook Salmon ESU to be in serious danger or threatened by present or threatened modification or destruction of habitat.

3. **Overexploitation:** Current ocean commercial and sport fisheries do not discriminate UKTR spring fall Chinook Salmon from UKTR fall Chinook Salmon. Also, direct estimates for natural-origin UKTR spring Chinook Salmon ocean catch are not feasible; however, marked and tagged TRH UKTR spring Chinook Salmon can be used to estimate ocean fishing impacts to the spring ecotype. Most UKTR Chinook Salmon (both spring and fall ecotypes) are harvested in the Klamath Management Zone and Fort Bragg areas, but the highest harvest index is in the Central Oregon zone. The commercial fishery accounts for the majority of UKTR spring Chinook Salmon ocean catch. Catch is split evenly between Oregon and California. Ocean harvest of hatchery UKTR spring Chinook Salmon is small in comparison to that for UKTR fall Chinook Salmon and other Chinook Salmon stocks.

   Except when *de minimus* fisheries are authorized, UKTR fall Chinook Salmon are managed for a conservation floor target of 40,700 natural area adults annually. The overall harvest rate is determined by the PFMC with NMFS guidance on an annual basis resulting in impact rates to the stock designed to achieve the conservation escapement target. Ocean fisheries are structured by area and season and in-river by quotas to target the overall impact rate cap. In-river harvest, both recreational and tribal, are governed by quotas determined by the PMFC that target in-river escapement objectives.

Tribal quotas tend to be higher than in-river sport quotas because most of the non-tribal allocation is apportioned to ocean fisheries. UKTR spring and fall Chinook Salmon are important cultural and nutritional Klamath tribal fisheries. The Hoopa Valley and Yurok tribal long-term annual average harvest is about 4,000 UKTR spring Chinook Salmon. The Yurok tribal harvest is usually greater than the Hoopa tribal harvest. Recent total tribal harvest numbers have declined to approximately 1,000+ UKTR spring Chinook Salmon.

Sport harvest of UKTR spring Chinook Salmon has declined both in relation to peak harvest in the mid-1980s and again since 2012. On average, sport harvest is larger in the Trinity basin than the Klamath basin. Overall sport harvest of UKTR spring Chinook Salmon is moderate in comparison to combined population component size in both the Klamath and Trinity rivers. Larger harvest in the Upper Trinity River at current levels is likely supportable due to the presence of generally larger numbers there and the presence of hatchery-origin UKTR spring Chinook Salmon from TRH. There is currently no harvest of UKTR spring Chinook Salmon in the Salmon River; however, given the low abundance of UKTR spring Chinook Salmon found in that river, fisheries in the lower Klamath River that impact Salmon River spring Chinook Salmon deserve more scrutiny.

Although the UKTR fall Chinook Salmon are currently considered overfished by the PFMC, overall numbers of the UKTR Chinook Salmon ESU remain relatively high. Therefore, the Department does not consider the continued existence of the UKTR Chinook Salmon ESU to be in serious danger or threatened by overexploitation.

4. **Predation:** UKTR Chinook Salmon are preyed upon by a variety of natural and introduced predators. However, predation is not thought to be a primary factor causing declines in UKTR Chinook Salmon. Pinniped predation on UKTR Chinook Salmon may be an added stressor for UKTR Chinook Salmon; however, pinniped predation alone does not considerably affect the ability of the UKTR Chinook Salmon ESU to survive and reproduce. The number of combined UKTR Chinook Salmon from fall and spring ecotypes remains large and distributed across the basin. Therefore, the Department does not consider the continued existence of the UKTR Chinook Salmon ESU’s to be in serious danger or threatened by predation.
5. **Competition:** Non-native and native salmonids and hatchery-origin fish may compete with UKTR Chinook Salmon when times and areas overlap; however, the effects of these and many of the invasive species in the basin are uncertain, as little quantitative information exists to evaluate their possible impacts. Evidence of large numbers of the combined UKTR Chinook Salmon ESU suggest that, while competition may be a limiting factor at some level, it does not pose a serious threat to continued existence of the ESU. Therefore, the Department does not consider the continued existence of the UKTR Chinook Salmon ESU to be in serious danger or threatened by competition.

6.

Disease: Juvenile and adult fish kills have been common in the Klamath River. The parasite *C. shasta* is implicated in high juvenile mortality. Columnaris infections and associated low flows that concentrate fish and disease vectors have affected Chinook Salmon abundance in the Klamath. Measures are in place to reduce and control disease and proposed dam removal may substantially decrease disease impacts. UKTR Chinook Salmon ESU abundance remains high in the face of substantial disease issues in the drainage.

Dam removal, planned to begin in 2022 if permits are received on schedule, has the potential to change the ecological setting (flows) in a way that selects against some disease organisms. Although speculative, disease organisms and their impacts on anadromous fish may be very different, possibly less than at present, under restored river flow conditions.

Therefore, while an area of concern for overall productivity of the ESU, the Department does not consider the continued existence of the UKTR Chinook Salmon ESU to be in serious danger or threatened by disease.

7. **Other natural occurrences or human-related activities:** Climate change projections for the Klamath basin predict warmer water temperatures during the summer and fall that will likely affect habitat suitability for salmonids including UKTR spring Chinook Salmon. How this future projection will be affected by dam removal is not known. Marine survival is strongly influenced by ocean climate patterns that vary on annual and decadal or longer scales. Ocean cycles will continue to affect annual abundance and timing of salmonids in the region. Drought is expected to be a periodic stressor across the state. The UKTR Chinook Salmon spring ecotype is likely more vulnerable than the fall ecotype to a warming climate and drought because of their migration timing and time spent in-river; however, the potential for climate change to increase the threat to continued existence of the UKTR Chinook Salmon ESU is not known for certain.

Hatcheries in the region produce large numbers of UKTR fall Chinook Salmon and more modest numbers of UKTR spring Chinook Salmon. Hatchery fish are likely to have both positive and negative effects on natural-origin UKTR Chinook Salmon. Most hatchery influence appears to be in the vicinity of the hatchery. Because only TRH produces UKTR spring Chinook Salmon, spring hatchery fish mostly impact the Upper Trinity River UKTR spring Chinook Salmon spawning aggregation, and to a lesser degree, the South Fork Trinity River spawning aggregation. Hatchery strays to the Salmon River and other parts of the Trinity River are uncommon. The UKTR fall Chinook Salmon programs at TRH and IGH currently supplement fall abundance throughout the drainage. The UKTR spring Chinook Salmon program at TRH supplements the spring ecotype, mostly in the upper Trinity River. Rough estimates of Proportionate Natural Influence (PNI) for the Upper

Trinity River UKTR spring Chinook Salmon group does not currently meet accepted conservation guidelines for protection of natural stocks. Data are not available to allow PNI calculations throughout the drainage; however, UKTR spring Chinook Salmon PNI is likely much higher in areas distant from TRH. Future UKTR fall Chinook Salmon production at IGH is uncertain because of the potential dam removal and dewatering of the hatchery.

Human-related activities likely affect overall UKTR Chinook Salmon ESU productivity; however, due to the large abundance of the UKTR Chinook Salmon ESU, the Department does not consider the continued existence of the UKTR Chinook Salmon ESU to be in serious danger or threatened by other natural occurrences or human-related activities.

9. Protections Afforded by CESA Listing

It is the policy of the state to conserve, protect, restore, and enhance any endangered or threatened species and its habitat (Fish & Game Code, § 2052). The conservation, protection, and enhancement of listed species and their habitat is of statewide concern (Fish & Game Code, § 2051(c)). If listed, unauthorized take of UKTR spring Chinook Salmon would be prohibited under state law. Under CESA “take” is defined as to hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill a listed species (Fish & Game Code, § 86). Any person violating the take prohibition would be punishable under state law. The Fish and Game Code provides the Department with related authority to authorize “take” of species listed as threatened or endangered under certain circumstances (see, e.g., Fish & Game Code, §§ 2081, 2081.1, 2086, & 2835). In general, and even as authorized, however, impacts of the taking caused by the activity must be minimized and fully mitigated according to state standards.

Should the Commission decide to list UKTR spring Chinook Salmon, management and other implementation of CESA will likely be complicated by 1) interbreeding and difficulties differentiating between UKTR spring and fall Chinook Salmon, and 2) interactions of UKTR spring Chinook Salmon with ocean fisheries that are managed in conjunction with federal processes. UKTR spring Chinook Salmon are a part of economically important recreational, commercial, and tribal fisheries in the Klamath-Trinity basin and in the ocean off the California and Oregon coasts. Inland fishery protection may be possible to some extent by focused additional time-area closures within the drainage (e.g., Salmon River). However, because UKTR spring Chinook Salmon are present in the ocean as a mixed stock with UKTR fall Chinook Salmon, and they are not distinguishable from the more abundant fall stock, it would be difficult or impossible to provide meaningful protections in ocean fisheries absent severe fishery reductions or complete fishery closure.

Commented [SN108]: It is fine to point out complexities but difficulty should not be posed as a reason for/against listing.

Commented [SN109]: Markers from Chr28 could be incorporated into mixed stock analyses to identify spring run fish

If the UKTR spring Chinook Salmon is listed under CESA, take impacts resulting from activities authorized through incidental take permits must be minimized and fully mitigated according to state standards (Fish & Game Code, § 2081, subd. (b)). These standards typically include protection of land in perpetuity with an easement, development and implementation of a species-specific adaptive management plan, and funding through an endowment to pay for long-term monitoring and maintenance to ensure the mitigation land meets performance criteria. Obtaining an incidental take permit is voluntary. The Department cannot force compliance; however, any person violating the take prohibition may be criminally and civilly liable under state law. Research and monitoring in watersheds populated by UKTR spring Chinook Salmon would be regulated by issuance of permits or memorandums of understanding under Fish and Game Code Section 2081, subdivision (a).

Additional protection of UKTR spring Chinook Salmon following listing would be expected to occur through state and local agency environmental review under the California Environmental Quality Act (CEQA). CEQA requires affected public agencies to analyze and disclose project-related environmental effects, including potentially significant impacts on rare, threatened, and endangered species. In common practice, potential impacts to listed species are examined more closely in CEQA documents than potential impacts to unlisted species. Where significant impacts are identified under CEQA, the Department expects project-specific avoidance, minimization, and mitigation measures to benefit the species. State listing, in this respect, and consultation with the Department during state and local agency environmental review under CEQA, would be expected to benefit the UKTR spring Chinook Salmon in terms of reducing impacts from individual projects, which might otherwise occur absent listing.

CESA listing may prompt increased interagency coordination specific to UKTR spring Chinook Salmon conservation and protection and the likelihood that state and federal land and resource management agencies will allocate additional funds toward protection and recovery actions. In the case of the UKTR spring Chinook Salmon, some multi-agency efforts to protect the spring ecotype already exist due to regional interest in maintaining the spring ecotype, and the department’s recognition of the importance of the ecotype to diversity of the UKTR Chinook Salmon ESU. CESA listing could result in increased priority for limited conservation funds.

In addition, listing of UKTR spring Chinook Salmon could increase priority and available funding for recolonization efforts proposed for the ecotype post-dam removal. It should be noted that these activities will likely occur regardless of UKTR spring Chinook Salmon listing status.

Commented [SN110]: This should be expanded in an appropriate section to verify specific actions that will be taken if not listed

10. Degree and Immediacy of Threat

Genetic and other biological evidence show that UKTR spring Chinook Salmon are a polyphyletic group without substantial population genetic distinction from UKTR fall Chinook Salmon. Although UKTR spring Chinook Salmon exhibit genetic and ecological differences from UKTR fall Chinook Salmon, these differences are at the level of an ecotype, not a separate ESU. Based on the available evidence the Department concludes that the combination of UKTR spring and fall Chinook Salmon into a combined UKTR Chinook Salmon ESU is valid and justifiable~~.~~ yet both ecotypes are necessary to viability of the ESU.~~.~~ Although spawning fish abundance estimates for the entire basin are incomplete, available data and analyses suggest that extinction risk at the UKTR Chinook Salmon ESU-level is low.

Commented [AC111]: Changes made by Shawn Narum

Based on long- and short-term evaluations, and climate warming predictions, it seems likely that UKTR spring Chinook Salmon in the Salmon and South Fork Trinity rivers could be extirpated as an ecotype in those places, and that extirpation could progress rapidly. However, because the "spring allele" is present in other locations in the basin (most notably in the UKTR spring Chinook Salmon groups from the Upper Trinity and TRH) and elsewhere, it is possible that the ecotype could be regenerated if conditions change or if assisted conservation actions that favor UKTR spring Chinook Salmon (e.g., active reintroduction and introduction of spring alleles) are taken.

Commented [SN112]: This appears accurate based on information in this report, but the points on lines 4579-4583 seem to contradict this statement

Commented [SN113]: Indeed, this action would be needed since it is highly unlikely they would be regenerated from standing genetic variation

Accurate assessment of the degree and immediacy of threat to the UKTR Chinook Salmon ESU is further complicated by the planned removal of four dams on the Klamath River, currently scheduled to begin 2022 assuming that permits are granted by that time. Dam removal will open large spawning and rearing areas that have been blocked to UKTR Chinook Salmon for decades. Dams have been cited in this and other reviews as a major limiting factor for UKTR spring Chinook Salmon. Because of their abundance and distribution in the basin, UKTR fall Chinook Salmon (and steelhead) may rapidly and naturally colonize the Upper Klamath River. However, because of the small number of UKTR spring Chinook Salmon present in only one place In the Klamath River basin (mostly in the Salmon River) and the distance to the nearest more abundant spring Chinook Salmon spawning assemblage (Upper Trinity River and TRH), unassisted natural recolonization of the Upper Klamath by UKTR spring Chinook Salmon post dam removal seems likely to take a long time and more immediate actions to introduce spring run fish with early alleles may be necessary for colonization to occur in conservation relevant timeframes.

Commented [AC114]: Changes made by Shawn Narum

Based on the considerations outlined above, overall, the Department believes the degree and immediacy of threat for the combined UKTR Chinook Salmon ESU is low but conservation actions are warranted for the spring run ecotype within this ESU. These conservation actions include…~~.~~

Commented [SN115]: Even if not listed separately, it seems necessary to recognize that actions are needed for the spring run ecotype

11. Listing Recommendation

In response to the listing petition received by the California Fish and Game Commission, CESA directs the Department to prepare a status review report for UKTR spring Chinook Salmon using the best scientific information available. (Fish & Game Code, § 2074.6.) CESA also directs the Department to recommend whether the petitioned action is warranted. (Fish & Game Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f).)

Under CESA, an endangered species is defined as “a native species or subspecies…which is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease.” (Fish & Game Code, § 2062.) A threatened species is defined as “a native species or subspecies…that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by [CESA].” (Fish & Game Code, § 2067.)

The Department’s status review recommendation is submitted to the Commission in an advisory capacity based on the best available science. In consideration of the scientific information contained herein, the Department recommendation is that UKTR spring Chinook Salmon should not be listed as a threatened or endangered species under the CESA. The Department arrives at this recommendation based on the following:

1. The petitioners request that the Commission list UKTR spring Chinook Salmon as endangered based on its qualification as a new ESU. Based on the best scientific information available at this time, the Department has determined that UKTR spring Chinook Salmon do not qualify as a separate ESU. UKTR spring Chinook Salmon are not reproductively isolated from UKTR fall Chinook Salmon. Genetic diversity in the UKTR Chinook Salmon ESU is structured by geography more than by run timing. The UKTR spring Chinook Salmon are best described as an ecotype, or genetic diversity element, of the combined UKTR Chinook Salmon ESU.
2. The UKTR Chinook Salmon ESU’s continued existence is not in serious danger or threatened by habitat modification. Although substantial habitat modification has occurred in the Klamath basin, and those modifications have affected UKTR Chinook Salmon, the UKTR Chinook Salmon are widely distributed in both the Klamath and Trinity Rivers in large numbers.
3. The UKTR Chinook Salmon ESU’s continued existence is not in serious danger or threatened by overexploitation. Although the fall stock is considered overfished by the PFMC, the overall numbers of fish in the ESU continue to be large. Both in-river and ocean fisheries are managed for minimum abundance in the tens of thousands.
4. The UKTR Chinook Salmon ESU’s continued existence is not in serious danger or threatened by predation. There are numerous predators of UKTR Chinook Salmon, including native and non-native fish species, and pinnipeds; however, predation is not

Commented [SN116]: This statement does not adequately account for the point made in the earlier section on lines 4526-4528

Commented [SN117]: I encourage including a recommendation to monitor ocean fisheries for harvest of fish with early alleles based on genetic markers from GREB1L/ROCK1 thought to be a limiting factor for the ESU. Overall, abundance of the combined UKTR Chinook Salmon ESU is large.

5. The UKTR Chinook Salmon ESU’s continued existence is not in serious danger or threatened by competition. Evidence of large numbers of the combined UKTR Chinook Salmon ESU suggest that, while competition may be a limiting factor at some level, it does not pose a serious threat to continued existence of the ESU.
6. The UKTR Chinook Salmon ESU’s continued existence is not in serious danger or threatened by disease. Juvenile and adult fish kills are common in the Klamath River. However, management actions are in place to reduce their effect. Proposed dam removals may reduce incidence and severity of disease outbreaks. Although disease is a concern due to its effect on total productivity of the ESU, disease does not pose a serious threat to continued existence of the ESU.
7. Human-related activities likely affect overall UKTR Chinook Salmon ESU productivity. However, due to the large abundance of the UKTR Chinook Salmon ESU, the Department finds that the UKTR Chinook Salmon ESU’s continued existence is not in serious danger or threatened by other natural occurrences or human-related activities.

12. Alternatives to Listing

If the Commission determines that listing is not warranted, the UKTR spring Chinook Salmon will revert to the unlisted status under state law that it held prior to the petition filing. Although unlisted, UKTR spring Chinook Salmon would continue to be on the list of Species of Special Concern. Projects with the potential to take UKTR spring Chinook Salmon will not be required to obtain State incidental take permits; however, the existing federal and state permit requirements that existed prior to the petition filing will remain in place. For example, the state will continue to negotiate Streambed Alteration Agreements and comment on Timber Harvest Plans, federal incidental take permits and recovery planning (if UKTR spring Chinook Salmon are listed under the ESA), and applications to the State Water Resources Control Board. Also, the Department of Fish and Wildlife will continue to act as the trustee agency for the state's fish, wildlife, and plant resources. In this role, the Department will review and comment on impacts to UKTR spring Chinook Salmon and recommend mitigation measures for these impacts as part of the CEQA review process.

In the absence of a decision by the Commission to list UKTR spring Chinook Salmon, the Department would also continue to participate in and support current or future programs designed to benefit UKTR spring Chinook Salmon and other anadromous fish including: coordination with other agencies on removal of four dams on the Klamath River (currently scheduled to begin 2022), participation on forums guiding and advising IGH operations and modifications pre- and post-Klamath dam removal, implementing recommendations of the CA HSRG (2012) for Trinity River Hatchery, coordination of operations supporting artificial propagation of UKTR spring and fall Chinook Salmon at TRH, coordination with ODFW on a reintroduction plan for the Upper Klamath River post-dam removal, prevention and treatment of disease, development and implementation of Hatchery and Genetic Management Plans, coordination with state agencies to decrease impacts from timber related projects, continue efforts to improve habitat for UKTR spring Chinook Salmon, identify/removing/retrofitting existing barriers to fish passage, working with gravel extractors and other mining interests to avoid, minimize, or mitigate for impacts to fisheries resources, continuing to restore and enhance salmon and steelhead habitat throughout the state through the Fisheries Restoration Grants Program and other granting programs, participation in federal and state conservation and restoration programs operating in the petitioned area, regulation of UKTR spring Chinook Salmon inland sport fishing, regulation and monitoring of ocean salmon fisheries, conducting research and monitoring programs, and coordinating with other agency research and monitoring efforts.

Commented [SN118]: These are important actions that should be referenced in the three previous sections where I noted

13. Recovery Considerations

The Department's recovery objective for UKTR spring Chinook Salmon is to protect and expand existing natural-origin spawning populations and reestablish enough additional native populations in restored and protected streams to ensure persistence over a minimum 100-year time frame. Increased numbers, expanded distribution, and metapopulation development will improve their probability of long-term survival within their native range in the Klamath Basin. Recovery actions would focus on 1) restoring, rehabilitating, and protecting habitat in natural spawning areas, and 2) improving conservation hatchery elements at Trinity River Hatchery in support of natural UKTR spring Chinook Salmon recovery, in accordance with state statute and Commission and Department policies.

Commented [SN119]: Reference in earlier sections

The current plan to remove four large dams on the Klamath River, a massive change in the Klamath River ecosystem, contributes substantial uncertainty about UKTR spring Chinook Salmon natural recovery potential. Overall, dam removal that results in a free-flowing river should be positive for all aquatic species in the basin.

State statute and Commission policy places management emphasis and priority on natural rather than hatchery-origin stocks. For example, Fish and Game Code Section 6901 states:

- Proper salmon and steelhead trout resource management requires maintaining adequate levels of natural, as compared to hatchery, spawning and rearing.
- Reliance upon hatchery production of salmon and steelhead trout in California is at or near the maximum percentage that it should occupy in the mix of natural and artificial hatchery production in the state. Hatchery production may be an appropriate means of protecting and increasing salmon and steelhead in specific situations; however, when both are feasible alternatives, preference shall be given to natural production.
- The protection of, and increase in, the naturally spawning salmon and steelhead trout of the state must be accomplished primarily through the improvement of stream habitat.

Also, the Commission policy on Cooperatively Operated Rearing Programs for Salmon and Steelhead states: “The bulk of the state’s salmon and steelhead resources shall be produced naturally. The state’s goals of maintaining and increasing natural production take precedence over the goals of cooperatively operated rearing programs.” The Commission policy on salmon states that “salmon shall be managed to protect, restore, and maintain the populations and genetic integrity of all identifiable stocks. Naturally spawned salmon shall provide the foundation for the Department’s management program.”

Commented [SN120]: This is fine to aim for large portion of natural spawning, but not likely to be fully satisfactory to meet obligations to the tribes for their rights to sustainable harvest. Options exist for supplementation with natural origin broodstock programs that could be presented.

Recovery also mandates effective monitoring of long-term status and trend of UKTR spring Chinook Salmon abundance and distribution throughout the petitioned area, as well as within sub-watersheds, is necessary. Recovery goals must ensure that individual populations and collective metapopulation(s), are sufficiently abundant to avoid genetic risks of small population size. Therefore, these goals need to address abundance levels (adult spawning escapements), population stability criteria, distribution, and length of time for determining sustainability.

Commented [SN121]: Again, supplementation with natural broodstock programs is a direct action to address these goals that are not likely to be met otherwise.

If listed under CESA, the Department will develop appropriate down listing or delisting criteria for UKTR spring Chinook Salmon, based on the best scientific information available. The department will periodically reexamine the status of UKTR spring Chinook Salmon. When, in the Department's judgment, recovery goals and down listing or delisting criteria have been met, the department will make recommendations to the Commission regarding changing the status of this species.

Recovery of viable UKTR spring Chinook Salmon populations in the Klamath basin will require vigorous efforts by the Department, other government agencies, and the private sector to improve and expand habitat and support population expansion. Watershed, water flow and quality, and habitat conditions must be improved to provide the necessary spawning and rearing habitat to allow the natural UKTR spring Chinook Salmon population components to survive, diversify, and increase to levels sufficient to withstand droughts, unfavorable climatic and oceanic conditions, and other uncontrollable natural phenomenon.

Commented [SN122]: Yes, and this should be briefly referenced in earlier sections.

Reintroduction and expansion of naturally reproducing UKTR spring Chinook Salmon populations, especially in the restored (i.e., post-dam removal) Klamath River, may require artificial propagation. These activities would be conducted under Department authority in cooperation with federal, local, and tribal governments and stakeholders. Trinity River Hatchery already produces UKTR spring Chinook Salmon and, if necessary, could be either 1) modified to include a conservation hatchery element, or 2) modified to develop a separate program focused on UKTR spring Chinook Salmon conservation.

14. Management Recommendations

Regardless of whether the Commission decides to list UKTR spring Chinook Salmon as a threatened or endangered species under CESA, the Department recommends the following management changes to support existing small and fragmented UKTR spring Chinook Salmon population components:

1. Investigate use of *GREB1L/ROCK1* gene for genetic stock identification in both ocean and inland fisheries. Collection and analysis of genetic data have high potential to provide information about ocean distribution of both natural- and hatchery-origin UKTR spring Chinook Salmon.
2. Produce and submit a Hatchery and Genetic Management Plan (HGMP) for TRH's UKTR spring and fall Chinook Salmon programs. This HGMP would include a plan to add a conservation hatchery element to the UKTR spring Chinook Salmon program at TRH. This could either be a modification of the existing program to include conservation elements, or a separate smaller program focusing on conservation of the spring ecotype.
3. Implement CA HSRG (2012) recommendations for Trinity River Hatchery's UKTR spring and fall Chinook Salmon programs through the existing multiagency, multidisciplinary Hatchery Coordination Team.
4. Pursue a plan to introduce and amplify the spring allele in existing Klamath River Chinook. A preliminary plan to cross TRH spring Chinook Salmon with IGH (Klamath River) fall Chinook Salmon exists as a potential element of the reintroduction plan for the Klamath River post-dam removal.
5. Develop a monitoring plan for UKTR spring Chinook Salmon natural recovery in the Klamath River post dam removal.
6. Continue coordination with ODFW on a salmonid reintroduction plan, especially for UKTR spring Chinook Salmon, for the Klamath River post dam removal.
7. Implement the California Coastal Monitoring Plan (CMP; Adams et al. 2011) for UKTR spring Chinook Salmon in both the Klamath and Trinity rivers to obtain robust and unbiased estimates of both UKTR spring and fall Chinook Salmon status and trend throughout the basin.
8. Implement measures to improve the proportion of natural-origin fish used as broodstock in TRH's UKTR spring Chinook Salmon hatchery program and measures to reduce the proportion of hatchery-origin fish on natural spawning grounds in the Upper Trinity River such that the Proportionate Natural Influence (PNI) is at least 0.67 in accordance with CA HSRG (2012) guidelines.
9. Implement one of the following marking/tagging strategies for UKTR spring and fall Chinook Salmon at TRH: a) 100% CWT and adipose fin-flip, or b) the CA HSRG recommendation of 100% CWT and 25% adipose fin-clip.

Commented [SC123]: If this plan exists as a written document then it should be cited here. If not, then I would recommend not including this bullet, or else expanding. I'm concerned that this could be read as a non-specific recommendation regarding genetic engineering of a population of conservation concern, and may pose downstream challenges.

Commented [SN124]: These are good management recommendations that should help with protection of the spring run ecotype

Commented [SN125]: Increasing proportion of natural origin broodstock (pNOB) is also a key component of PNI and often more straightforward to control. Aim for high proportion of pNOB.

Commented [SN126]: Several analyses indicate that 100% PBT would be more efficient and equally effective as 100% CWT

10. Consider development of a mark-select fishery for in-river spring sport harvest in the Upper Trinity River to reduce hatchery-origin fish numbers on natural spawning grounds. This would likely require 100% adipose fin-clip marks for all TRH UKTR spring Chinook Salmon.

Commented [SN127]: Mark selective fisheries can have substantial negative impacts to natural origin fish and should only be implemented with extreme caution

We also recommend adoption and implementation of the following management recommendations proposed in Moyle et al. (2015):

11. Follow-through with plans to remove mainstem Klamath River dams;
12. Restore cold-water refugia on the Shasta River;
13. Manage the Salmon River as a refuge for UKTR spring Chinook Salmon (and summer steelhead),
14. Develop and implement in-hatchery and in-stream monitoring to assess TRH hatchery impacts on natural stocks;
15. Accelerate habitat restoration to mitigate impacts from roads and logging; and
16. Revisit ocean and inland harvest to consider specific impacts to UKTR spring Chinook Salmon.

Commented [SN128]: These are good recommendations

15. Economic Considerations

The Department is charged in an advisory capacity to the Fish and Game Commission to provide a written status review report and a resultant recommendation based on the best scientific information available regarding the status of the UKTR spring Chinook Salmon in California. The Department is not required to prepare an analysis of economic impacts (See Fish & Game Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f)).

Literature Cited

Adams, P. B., L. B. Boydstun, S. P. Gallagher, M. K. Lacy, T. McDonald, and K. E. Shaffer. 2011. California coastal salmonid population monitoring: strategy, design, and methods. California Department of Fish and Game Fish Bulletin 180.

Allen, M. A. 2000. Seasonal microhabitat use by juvenile spring Chinook Salmon in the Yakima River basin, Washington. Rivers 7(4):314-322.

Allendorf, F. W., P. A. Hohenlohe, and G. Luikart. 2010. Genomics and the future of conservation genetics. Nature Reviews Genetics 11:697-709.

Anderson, E. C., M. J. Ford, J. C. Garza and J. D. Kiernan. 2018. Upper Klamath and Trinity River Chinook Salmon ESU- configuration Review - panel report, A report to the National Marine Fisheries Service West Coast Region – Protected Resources Division from Southwest Fisheries Science Center, 110 McAllister Way, Santa Cruz, CA 95060.

Anderson, E. C., M. J. Ford, J. C. Garza, and J. D. Kiernan. 2019. Upper Klamath and Trinity River Chinook Salmon ESU-Configuration Review-Panel Report. Report from Southwest Fisheries Science Center to West Coast Region, Protected Resources Division. Update of 15 June 2018 report. 24 April 2019. NMFS Southwest Fisheries Science Center, 110 McAllister Way, Santa Cruz, CA 95060.

Anderson, E. C. and J. C. Garza. 2019. Supplemental and recent findings pertinent to ESU configuration of the Upper Klamath Trinity River Chinook salmon ESU, A report to the National Marine Fisheries Service West Coast Region – Protected Resources Division from Southwest Fisheries Science Center, Santa Cruz, CA.

Augerot, X., and D.N. Foley. 2005. Atlas of Pacific Salmon. Pp. 80-83. University of California Press, Berkeley.

Banks, M., and M. Barton. 1999. Microsatellite DNA variation among Klamath River Chinook salmon sampled from fall and spring runs. Yurok Tribe Fisheries Program. Klamath, CA.

Banks, M., M. Barton, and P. Berrebi. 2000a. Microsatellite DNA variation among Klamath River chinook Salmon. Final Report, submitted to Yurok Tribe Fisheries Program. Klamath, CA.

Banks, M. A., V. K. Rashbrook, M. J. Calavetta, C. A. Dean, and D. Hedgecock. 2000b. Analysis of microsatellite DNA resolves genetic structure and diversity of chinook salmon in California's Central Valley. Canadian Journal of Fisheries and Aquatic Sciences 57:915-927.

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Barnhart, R. A. 1994. Salmon and steelhead populations of the Klamath-Trinity Basin, California. Pages 73-97 in T. J. Hassler, editor. Klamath Basin fisheries symposium. California Cooperative Fishery Research Unit, Humboldt State University, Arcata, CA.

Barnhart, R. A., and D. C. Hillemeier. 1994. Summer habitat utilization by adult spring Chinook Salmon and summer steelhead, South Fork Trinity River, California. Final Report, California Cooperative Fishery Research Unit, Humboldt State University, Arcata, CA.

Barr, B. R., M. E. Koopman, C. D. Williams, S. J. Vynne, R. Hamilton, and B. Doppelt. 2010. Preparing for climate change in the Klamath Basin. National Center for Conservation Science & Policy and The Climate Leadership Initiative.

Bartholow, J. M. 2005. Recent water temperature trends in the Lower Klamath River, California. North American Journal of Fisheries Management 25:152-162.

Beer, W. N., and E. A. Steel. 2018. Impacts and Implications of temperature variability on Chinook Salmon egg development and emergence phenology. Transactions of the American Fisheries Society 147:3-15.

Belchik, M. 1997. Summer locations and salmonid use of cool water areas in the Klamath River. Iron Gate Dam to Seiad Creek, 1996. Yurok Tribal Fisheries Program. Klamath, CA.

Bjornn, T. C. 1969. Embryo survival and emergence studies, Job. No. 5, Federal Aid in Fish and Wildlife Restoration. Job Completion Rep., Proj. F-49-R7. Idaho Fish and Game Department, Boise.

Bjornn, T. C., and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society. Special Publication 19:83-138.

Bourret, S. L., C. C. Caudill, M. L. Keefer. 2016. Diversity of juvenile Chinook Salmon life history pathways. Reviews in Fish Biology and Fisheries 26(3):375-403.

Buchanan, R., R. Townsend, J. Skalski, and K. Ham. 2011. The effect of bypass passage on adult returns of Salmon and steelhead: an analysis of PIT-tag data using the program ROSTER. Final Report. Prepared by Battelle, Pacific Northwest Division, Richland, Washington for U.S. Army Corps of Engineers, Walla Walla District, WA.

Buffington, J., C. Jordan, M. Merigliano, J. Peterson, and C. Stalnaker. 2014. Review of the Trinity River Restoration Program following Phase 1, with emphasis on the program's channel rehabilitation strategy. Prepared by the Trinity River Restoration Program's Science Advisory Board with assistance from Anchor QEA, LLC, Stillwater Sciences, BioAnalysts, Inc., and Hinrichsen Environmental Services. Accessed at: https://www.trrp.net/library/document/?id=2172

Formatted: Swedish (Sweden)

Busch, D. S., C. J. Harvey, P. McElhany. 2013. Potential impacts of ocean acidification on the Puget Sound food web. ICES J Mar Sci. 70(4):823–33. https://doi.org/10.1093/icesjms/fst061

Busch, D. S., P. McElhany. 2016. Estimates of the direct effect of seawater pH on the survival rate of species groups in the California Current ecosystem. PLoS ONE. 2016; 11(8):e0160669. Epub 2016/08/12.

Burns, J. W. 1972. Some effects of logging and associated road construction on northern California streams. Transactions of the American Fisheries Society 101:1-17.

California Department of Fish and Game (CDFG). 1965. California Fish and Wildlife Plan. Volume III, Supporting Data. Part B – Inventory salmon-steelhead and marine resources.

California Department of Fish and Game (CDFG). 1998. A status review of the spring-run Chinook Salmon (*Oncorhynchus tshawytscha*) in the Sacramento River drainage. Candidate Status Report 98-01. California Department of Fish and Game (Wildlife), Sacramento CA.

California Department of Fish and Game (CDFG). 2002. Status review of California Coho Salmon north of San Francisco. Report to The California Fish and Game Commission. April 2002.

California Department of Fish and Game (CDFG). 2003. September 2002 Klamath River fish kill: Preliminary analysis of contributing factors special report. California Department of Fish and Game (Wildlife), Northern Region, Redding CA.

California Department of Fish and Game (CDFG). 2004. September 2002 Klamath River Fish-Kill: Final Analysis of Contributing Factors and Impacts. California Department of Fish and Game (Wildlife), Northern Region, Redding CA.

California Department of Fish and Game (CDFG). 2011a. Klamath River basin fall Chinook salmon spawner escapement, in-river harvest and run-size estimates, 1978–2010. Available from W. Sinnen, CDFG, 5341 Ericson Way, Arcata, CA 95521.

California Department of Fish and Game (CDFG). 2011b. Klamath River basin spring Chinook salmon spawner escapement, in-river harvest and run-size estimates, 1980–2009. Available from W. Sinnen, CDFG, 5341 Ericson Way, Arcata, CA 95521.

California Department of Fish and Wildlife (CDFW). 2015. Klamath River Basin spring Chinook Salmon spawner escapement, river harvest and run-size estimates, 1980 – 2014. Accessed at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=100231

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Formatted: Portuguese (Brazil)

California Department of Fish and Wildlife (CDFW). 2018a. Statewide drought response: stressor monitoring summary 2014-2017. California Department of Fish and Wildlife, Fisheries Branch. Sacramento, CA. Available from: http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=168170

California Department of Fish and Wildlife (CDFW). 2018b. Evaluation of the petition from the Karuk Tribe and the Salmon River Restoration Council to list Upper Klamath Trinity River spring Chinook Salmon (*Oncorhynchus tshawytscha*) as threatened or endangered. A report to the California Fish and Game Commission. November 2018.

California Department of Fish and Wildlife (CDFW). 2019. Annual report Trinity River basin salmon and steelhead monitoring project: Chinook and Coho Salmon and fall-run steelhead run-size estimates using mark recapture methods, 2018 – 19 Season. California Department of Fish and Wildlife, Northern Region, Klamath-Trinity Program. July 2019.

California Hatchery Scientific Review Group (CA HSRG). 2012. California hatchery review report. Prepared for the U.S. Fish and Wildlife Service and Pacific States Marine Fisheries Commission. April 2012.

Campbell, A., and P. B. Moyle. 1991. Historical and recent population sizes of spring-run Chinook Salmon in California. Pages 155-216 in T.J. Hassler, editor. Proceedings, Northeast Pacific Chinook and Coho Salmon Workshop. American Fisheries Society, Arcata, CA.

Carter, K., and S. Kirk. 2008. Fish and fishery resources of the Klamath River basin. 2008. Appendix 5 *in* North Coast Regional Water Quality Control Board. 2010. Final staff report for the Klamath River Total Maximum Daily Loads (TMDLs) addressing temperature, dissolved oxygen, nutrient, and microcystin impairments in California. The proposed site-specific dissolved oxygen objectives for the Klamath River in California and the Klamath River and Lost River Implementation plans. California Water Boards, North Coast Region, Santa Rosa, CA. Accessed at: https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/klamath_river/

Chaffin, B., R. K. Craig, and H. Gosnell. 2015. Resilience, adaptation, and transformation in the Klamath River basin socio-ecological system. 51 Idaho Law Review: 157-193.

Chamberlain, C. D., S. Quinn, and B. Matilton. 2012. Distribution and abundance of Chinook Salmon redds in the mainstem Trinity River 2002 – 2011. U.S. Fish and Wildlife Service. Arcata Fisheries Technical Report TR 2012-16. Accessed at: https://www.fws.gov/arcata/fisheries/reports/technical/Trinity_redd_2002_to_2011.pdf

Chiaramonte, L. V., R. A. Ray, R. A. Corum, T. Soto, S. L. Hallett, and J. L. Bartholomew. 2016. Klamath river thermal refuge provides juvenile Salmon reduced exposure to the parasite *Ceratonova shasta*. Transactions of the American Fisheries Society 145:810-820.

Clemento, A. J., E. D. Crandall, J. C. Garza, and E. C. Anderson. 2014. Evaluation of a single nucleotide polymorphism baseline for genetic stock identification of Chinook Salmon (*Oncorhynchus tshawytscha*) in the California Current large marine ecosystem. Fishery Bulletin 112(2-3):112-130.

Cline, T. J., J. Ohlberger, and D. E. Schindler. 2019. Effects of warming climate and competition in the ocean for life-histories of Pacific salmon. Nature Ecology & Evolution 3:935–942.

Coates, D. J., M. Byrne, and C. Moritz. 2018. Genetic diversity and conservation units: dealing with the species-population continuum in the age of genomics. Frontiers in Ecology and Evolution 6:165.

Coots, M. 1962. Shasta River, Siskiyou County, 1958 King Salmon count, with yearly totals from 1930-1961. California Department of Fish and Game, Inland Fisheries Branch, Sacramento, California.

Crête-Lafrenière, A., L. Weir., and L. Bernatchez. 2012. Framing the Salmonidae family phylogenic portrait: a more complete picture from increased taxon sampling. PLoS one. 7. E6662. 10.1371/journal.pone.0046662.

Crozier, L. G., M. M. McClure, T. Beechie, S. J. Bograd, D. A. Boughton, M. Carr, et al. 2019. Climate vulnerability assessment for Pacific salmon and steelhead in the California Current Large Marine Ecosystem. PLoS ONE 14(7): e0217711. https://doi.org/10.1371/journal.pone.0217711

Curran, M. A. J., T. D. van Ommen, V. I. Morgan, K. L. Phillips, and A. S. Palmer. 2003. Ice core evidence for Antarctic Sea ice decline since the 1950s. Science 302(5648):1203–1206.

Dean, M. 1996. Life history, distribution, run size, and harvest of spring Chinook Salmon in the South Fork Trinity Chapter VII, Annual Report, Trinity River Basin salmon and steelhead monitoring project, 1994 – 1995 season. California Department of Fish and Game, Inland Fisheries Division Sacramento**.**

De la Fuente, J. and P. A. Haessig, 1993, Salmon Sub-Basin Sediment Analysis, USDA – Forest Service, Klamath National Forest.

Dennis, B., P. L. Munholland, and J. M. Scott. 1991. Estimation of growth and extinction parameters for endangered species. Ecological Monographs 61:115-143.

Elder, D., B. Olson, A. Olson, J. Villeponteaux, and P. Brucker. 2002. Salmon River subbasin restoration strategy: steps to recovery and conservation of aquatic resources. Prepared by Klamath National Forest, Yreka California and Salmon River Restoration Council, Sawyers Bar, California for the Klamath Basin Restoration Task Force.

Formatted: English (United States)

Eschmeyer, W. N., W. W. Herald, and H. Hammann. 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Co., Boston, MA.

ESSA Technologies, Ltd. (ESSA). 2017. Klamath Basin Integrated Fisheries Restoration and Monitoring (IFRM) Synthesis Report. Pacific States Marine Fishery Commission, Portland, OR.

Federal Energy Regulatory Commission (FERC). 2007. Final Environmental Impact Statement for Hydropower License, Klamath Hydroelectric Project, FERC Project No. 2082-027, FERC/EIS-0201F. Washington, D.C., Federal Energy Regulatory Commission, Office of Energy Projects, Division of Hydropower Licensing.

Fetcho, K. 2006. Water Year 2005, Klamath River Blue-Green Algae Bloom Report. Yurok Tribe Environmental Program. Klamath, CA.

Flagg, T. A., B. A. Berejikian, J. E. Colt, W. W. Dickhoff, L. W. Harrell, D. J. Maynard, C. E. Nash, M. E. Strom, R. N. Iwamoto, and C. V. W. Mahnken. 2000. Ecological evaluation of the effect of hatcheries on wild salmon and behavioral impacts of artificial production strategies on the abundance of wild salmon populations—a review of practices in the Pacific Northwest. NOAA Technical Memorandum NMFS-NWFSC-41. U.S. Department of Commerce, Seattle, Washington.

Foott, J. S., D. Free, W. Talo, and J. D. Williamson. 1997. FY96 Investigational Report: physiological effects of *Nanophyetus Metacercaria* infection in Chinook Salmon smolts (Trinity River). U. S. Fish and Wildlife Service, California- Nevada Fish Health Center, Anderson, CA.

[15]Ford, M., K. Nichols, R. Waples, E. C. Anderson, M. Kardos, I. Koch, G. McKinney, M. R. Miller, J. Myers, K. Naish, S. Narum, K. G. O'Malley, D. Pearse, T. Seamons, A. Spidle, P. Swanson, T. Q. Thompson, K. Warheit, and S. Willis. 2020. Reviewing and Synthesizing the State of the Science Regarding Associations between Adult Run Timing and Specific Genotypes in Chinook Salmon and Steelhead: Report of a workshop held in Seattle, Washington, 27–28

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[15] The Northwest Fisheries Science Center of NOAA's National Marine Fisheries Service uses the NOAA Processed Report NMFS-NWFSC-PR series to disseminate information only. Manuscripts have not been peer-reviewed and may be unedited. Documents within this series represent sound professional work, but do not constitute formal publications. They should only be footnoted as a source of information and may not be cited as formal scientific literature. The data and any conclusions herein are provisional, and may be formally published elsewhere after appropriate review, augmentation, and editing. NWFSC Processed Reports are available from the NOAA Institutional Repository, https://repository.library.noaa.gov.

February 2020. U.S. Department of Commerce, NOAA Processed Report NMFS-NWFSC-PR-2020-06.

Fortune, J. D., A. R. Gerlach, and C. J. Hanel. 1966. A study to determine the feasibility of establishing salmon and steelhead in the Upper Klamath Basin. Oregon State Game Commission and Pacific Power and Light Company. Portland, OR.

Fraser, D. J., and L. Bernatchez. 2001. Adaptive evolutionary conservation: towards a unified concept for defining conservation units. Molecular Ecology 10:2741-2752.

Fresh, K. L., and S. L. Schroder. 1987. Influence of the abundance, size, and yolk reserves of juvenile Chum Salmon (*Oncorhynchus keta*) on predation by freshwater fishes in a small coastal stream. Canadian Journal of Fisheries and Aquatic Sciences 44(2):236-243.

Fuhrman, A. E., D. A. Larsen, E. A. Steel, G. Young, and B. R. Beckman. 2017. Ecology of Freshwater Fishes 2017:1-13.

Garza, J. C., S. M. Blankenship, C. Lemaire, and G. Charrier. 2007. Genetic population structure of Chinook Salmon (*Oncorhynchus tshawytscha*) in California's Central Valley. Final report: CalFed Project "Comprehensive evaluation of population structure and diversity for Central Valley Chinook Salmon".

Good, T. P., R. S. Waples, and P. Adams. 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. NOAA Technical Memorandum NMFS-NWFSC-66.

Goodman, D. H., A. Meartin, J. Alvarez., A. Davis, and J. Palos. 2010. Assessing Trinity River salmonid habitat at channel rehabilitation sites, 2007 – 2008. U.S. Fish and Wildlife Service, Yurok Tribe, and Hoopa Valley Tribe. June 2010.

Gresh, T., J. Lichatowich, and P. Schoonmaker. 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 25:15-21.

Griffith, J. S., and D. A. Andrews. 1981. Effects of a small suction dredge on fishes and aquatic invertebrates in Idaho streams. North American Journal of Fisheries Management 1:21-28.

Hamilton, J. B., G. L. Curtis, S. M. Snedaker, and D. K. White. 2005. Distribution of anadromous fishes in the upper Klamath River watershed prior to hydropower dams – a synthesis of historical evidence. Fisheries 30(4):10-20.

Hamilton, J. B., D. Rondorf, M. Hampton, R. Quinones, J. Simondet, and T. Smith. 2011. Synthesis of the effects to fish species of two management scenarios for the secretarial determination on removal of the lower four dams on the Klamath. Prepared by the

Biological Subgroup for the Secretarial Determination Regarding Potential Removal of the Lower Four Dams on the Klamath River.

Hamilton, J. B., D. W. Rondorf, W. T. Tinniswood, R. J. Leary, T. Mayer, C. Gavette, and L. A. Casal. 2016. The persistence and characteristics of Chinook Salmon migrations to the upper Klamath River prior to exclusion by dams. Oregon Historical Quarterly 117: 326–377.

Hampton, M. 1997. Microhabitat suitability criteria for anadromous Salmonids of the Trinity River. U.S. Fish and Wildlife Service, Arcata, CA.

Hardy, T. B., and R. C. Addley. 2006. Evaluation of interim instream flow needs in the Klamath River, Phase II, Final Report. Report prepared for USDI. Institute for Natural Systems Engineering. Utah Water Research Laboratory. Utah State University. Logan UT.

Hart, J. L., 1973. Pacific fishery of Canada. Fisheries Research Board of Canada Bulletin 180:740.

Harvey, B. C. 1986. Effects of suction gold dredging on fish and invertebrates in two California streams. North American Journal of Fisheries Management 6:401-409.

Harvey, B. C., and T. E. Lisle. 1998. Effects of suction dredging on streams: a review and an evaluation strategy. North American Journal of Fisheries Management 8:8-17.

Harvey, C., T. Garfield, G. Williams, N. Tolomieri (eds.). 2019. California current integrated ecosystem assessment (CCIEA). California current ecosystem status report, 2019.PSMFC Agenda Item E.1.a. IEA Team Report. March 2019. Available at: https://www.pcouncil.org/documents/2019/02/agenda-item-e-1-a-iea-team-report-1-california-current-integrated-ecosystem-assessment-cciea-california-current-ecosystem-status-report-2019.pdf/

Hatchery Scientific Review Group (HSRG). 2015. Annual Report to Congress on the Science of Hatcheries, 2015. A report on the application of up-to-date science in the management of Salmon and steelhead hatcheries in the Pacific Northwest.

Hawthorne, N. 2017. Estimating hydraulic mining disturbance to the Salmon River using LiDAR. Prepared in fulfillment of the Humboldt State University course in Geospatial Science in Research. December

Healey, M. C. 1991. Life history of Chinook Salmon *(Oncorhynchus tshawytscha).* In C. Groot and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press, Vancouver, Canada.

Hearn, W. 1987. Interspecific competition and habitat segregation among stream-dwelling trout and salmon. Fisheries 12(5):24-31.

Formatted: German (Germany)

Hess, J. E., J. S. Zendt, A. R. Matala, and S. R. Narum. 2016. Genetic basis of adult migration timing in anadromous steelhead discovered through multivariate association testing. Proceedings of the Royal Society B. 283:20153064.

Hillemeier, D. 1999. An assessment of pinniped predation upon fall-run Chinook Salmon in the lower Klamath River, CA, 1997. Yurok Tribal Fisheries Program. Klamath, CA. Accessed at: http://www.krisweb.com/biblio/klamath_yuroktfp_hillemeier_1997_pinnipeds.pdf

Hillemeier, D., and M. Farro. 1995. Final Report: Review and Evaluation of Horse Linto Creek Rearing Facility, 1985-1994. Arcata, CA.

Hillemeier, D., M. Belchik, T. Soto, S. Tucker, and S. Ledwin. 2017. Measures to reduce *Ceratonova shasta* infection of Klamath River salmonids: a guidance document. Disease Technical Advisory Team.

Horton, N. J., and K. P. Kleinman. 2007. Much ado about nothing: a comparison of missing data methods and software to fit incomplete data regression models. The American Statistician 61(1):79-90.

Horizon Water and Environment. 2012. Suction Dredge Permitting Program—Final Subsequent Environmental Impact Report. HWE 09.005. Oakland, CA.

Huntington, C. W. 2006. Estimates of anadromous fish runs above the site of Iron Gate Dam. Clearwater BioStudies, Canby, Oregon.

Huntington, C. W., E. W. Claire, F. A. Espinosa, Jr., and R. House. 2006. Reintroduction of anadromous fish to the Upper Klamath Basin: an evaluation and conceptual plan. Report to the Klamath Tribes and Yurok Tribes.

Independent Scientific Advisory Board (ISAB). 2005. Report on harvest management of Columbia basin salmon and steelhead. ISAB Harvest Report, ISAB 2005-4.

Integrated Hatchery Operations Team (IHOT) 1995. Policies and procedures for Columbia Basin anadromous salmonid hatcheries. Annual Report, 1994. Report to Bonneville Power Administration, Contract No. 1992B160629; BPA Report DOE/BP-60629. http://www.hatcheryreform.us/hrp/uploads/VAGREAJSVIM5/IHOT%20STANDARDS.pdf.

Intergovernmental Panel on Climate Change (IPCC). 2007. R. K. Pacharui and A. Reisinger, editors. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland. www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm.

Formatted: Font:

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

Jacox, M. G., C. A. Edwards, E. L. Hazen, and S. J. Bograd. 2018. Coastal upwelling revisited: Ekman, Bakun, and improved upwelling indices for the U.S. west coast. Journal of Geophysical Research: Oceans 123:7332-7350.

Karuk Tribe and Salmon River Restoration Council. 2018. Petition to the State of California Fish and Game Commission to list Klamath Trinity spring Chinook under the CESA.

Katz, J., P. B. Moyle, R. M., Quiñones, J. Israel, S. Purdy. 2012. Impending extinction of salmon, steelhead, and trout (Salmonidae) in California. Environmental Biology of Fishes 96:1169-1186.

Kier and Associates. 1999. Mid-term evaluation of the Klamath River Basin Fisheries Restoration Program. Prepared for the Klamath River Basin Fisheries Task Force and USFWS. Yreka, CA.

Kinziger, A. P., M. Hellmair, and D. G. Hankin. 2008a. Genetic structure of Chinook Salmon (*Oncorhynchus tshawytscha*) in the Klamath-Trinity Basin: implications for within-basin genetic stock identification. Produced under contract agreement between the Hoopa Valley Tribal Fisheries Department and Humboldt State University Sponsored Programs Foundation. Project received financial support by U.S. Bureau of Reclamation, Klamath Basin Area Office. (Full contract title: GSI Klamath Chinook, project number 1.22-4275).

Kinziger, A. P., M. Hellmair, D. G. Hankin, and J.C. Garza. 2013. Contemporary population structure in Klamath River basin Chinook Salmon revealed by analysis of microsatellite genetic data. Transactions of the American Fisheries Society 14(5):1347-1357.

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

Klamath River Basin Fisheries Task Force (KRBFTF). 1991. Long Range Plan for The Klamath River Basin Conservation Area Fishery Restoration Program. Assistance from William M. Kier Associates.

Klamath River Technical Team (KRTT). 2011. Klamath River fall Chinook salmon age specific escapement, river harvest, and run size estimates, 2010 run. Available from the Pacific Fishery Management Council, 7700NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Formatted: Spanish (United States)

Kondolf, G. M., and M. G. Wolman. 1993. The sizes of salmonid spawning gravels. Water Resources Research 29(7):2275-2285.

Krawchuk, M. A., M. A. Moritz. M.A. Parisien, J. Van Dorn, and K. Hayhoe. 2009. Global pyrogeography: The current and future distribution of wildfire. PLOS One 4(4): e5102.

Laake, J. L., M. S. Lowry, R. L. DeLong, S. R. Melin, and J. V. Carretta. 2018. Population growth and status of California sea lions. Journal of Wildlife Management 82:583-595.

Lane and Lane Associates. 1981. The Copco dams and the fisheries of the Klamath Tribe. Prepared for the Bureau of Indian Affairs. US Department of the Interior. Portland, Oregon.

La Faunce, D. A. 1967. A king salmon spawning survey of the South Fork Trinity River, 1964. CA Dept. Fish and Game, Mar. Res. Admin. Rep. No. 67-10.

Lara, W. 1993-1996. Yurok Accelerated Stocking Program for Klamath River Late Run Fall Chinook. Walt Lara, Jr., Klamath California. Cited in: Pacific Watershed Associates (PWA). 1994. Action Plan for restoration of the South Fork Trinity River watershed and its fisheries. Prepared for the US Bureau of Reclamation and the Trinity River Task Force. Accessed at: http://www.krisweb.com/biblio/sft_usbor_pwa_1994_sftplan/pwa1.htm

Leidy, R. A., and G. R. Leidy. 1984. Life stage periodicities of anadromous salmonids in the Klamath River basin, northwestern California. US Fish and Wildlife Service, Sacramento, CA.

Lestelle, L. 2012. Effects of Dwinnell Dam on Shasta River salmon and considerations for prioritizing recovery actions. Karuk Tribe, Happy Camp, CA.

Leitritz, E. and E. Lewis 1976. Trout and salmon culture (hatchery methods). California Department of Fish and Game, Fish Bulletin 164.

Levin, P. S., R. W. Zabel, and J. G. Williams. 2001. The road to extinction is paved with good intentions: negative associations of fish hatcheries with threatened salmon. Proceedings of the Royal Society B 268:1153-1158.

Levins, R. 1969. Some demographic and genetic consequences of environmental heterogeneity for biological control. Bulletin of the Entomological Society of America 15(3):237-240.

Lichatowich, J. 1999. Salmon without rivers: a history of the Pacific salmon crisis. Island Press, Washington, D.C.

Lindley, S. T., C. B. Grimes, M. S. Mohr, W. Peterson, J. Stein, J. T. Anderson, L. W. Botsford, , D. L. Bottom, C. A. Busack, T. K. Collier, J. Ferguson, J. C. Garza, A. M. Grover, D. G. Hankin, R. G. Kope, P. W. Lawson, A. Low, R. B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F. B.

Schwing, J. Smith, C. Tracy, R. Webb, B. K. Wells, and T. H. Williams. 2009. What caused the Sacramento River fall Chinook stock collapse? Pre-publication report to the Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Marine, K. R. and Cech, J. J. Jr., 2004, Effects of high water temperature on growth, smoltification, and predator avoidance in juvenile Sacramento River Chinook salmon: North American Journal of Fisheries Management, V. 24, p. 198–210.

Mathis, J. T., J. N. Cross, W. Evans, S. C. Doney. 2015. Ocean acidification in the surface waters of the Pacific-Arctic boundary regions. Oceanography. 28(2):122–35.

Matthews, K. R., and N. H. Berg. 1997. Rainbow trout responses to water temperature and dissolved oxygen stress in two southern California stream pools. Journal of Fish Biology, 50:50-67.

Mayr, E. 1966. Animal species and evolution. Harvard University Press. Cambridge, Mass.

McClure, M. M., E. E. Holmes, B. L. Sanderson, and C. E. Jordan. 2003. A large-scale multispecies status assessment: anadromous salmonids in the Columbia River basin. Ecological Applications, 13(4): 964-989.

McCuddin, M. E. 1977. Survival of salmon and trout embryos and fry in gravel-sand mixtures. M.S. thesis, University of Idaho, Moscow, ID.

McPhail. J. D, and C. C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Bulletin - Fisheries Research Board of Canada. 173:381.

Meehan, W. R. (editor). 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication No. 19.

Meek, M. H., M. R. Baerwald, M. R. Stephens, A. Goodbla, M. R. Miller, K.M.H. Tomalty, and B. May. 2016. Sequencing improves our ability to study threatened migratory species: Genetic population assignment in California's Central Valley Chinook Salmon. Ecology and Evolution 6: 7706–7716.

Moffett, J. W. and S. E. Smith. 1950. Biological Investigations of the fishery resources of Trinity River, California. Special Scientific Report: Fisheries No. 12. United States Fish and Wildlife Service. Washington, D.C.

Moran, P., D. J. Teel, M. A. Banks, T. D. Beacham, M. R. Bellinger, S. M. Blankenship, J. R. Candy, J. C. Garza, J. E. Hess, S. R. Narum, L. W. Seeb, W. D. Templin, C. G. Wallace, and C. T. Smith. 2013. Divergent life-history races do not represent Chinook Salmon coast-wide: the importance of scale in Quaternary biogeography. Canadian Journal of Fisheries and Aquatic Sciences 70: 415–435

Moritz, C. 1994. Defining ‘evolutionarily significant units’ for conservation. Trends in Ecology and Evolution, 9:373-375.

Morrison, W., M. Nelson, J. Howard, E. Teeters, J. A. Hare, R. Griffis. 2015. Methodology for assessing the vulnerability of fish stocks to changing climate. National Marine Fisheries Service, Office of Sustainable Fisheries. Report No.: NOAA Technical Memorandum NMFS-OSF-3.

Morrow, J. E. 1980. The freshwater fishes of Alaska. Alaska Northwest Publishing Co., Anchorage, AK.

Moyle, P. B. 1976. Inland fishes of California. University of California Press, Berkeley.

Moyle, P. B. 2002. Inland fishes of California. Second edition. University of California Press, Berkeley.

Moyle, P. B., J. A. Israel, and S. E. Purdy. 2008. Salmon, steelhead, and trout in California: status of emblematic fauna. A report commissioned by California Trout. Center for Watershed Sciences, University of California, Davis.

Moyle, P. B., J. V. E. Katz, R. M. Quiñones. 2011. Rapid decline of California’s native inland fishes: A status assessment. Biological Conservation 144(2011):2414-2423.

Moyle, P. B., R. Lusardi, and P. Samuel. 2017. “SOS II: Fish in Hot Water.” San Francisco, CA: California Trout. Accessed at: http://caltrout.org/sos/.

Moyle, P. B., R. M. Quiñones, J. V. Katz and J. Weaver. 2015. Fish Species of Special Concern in California. Sacramento: California Department of Fish and Wildlife.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. Fish species of special concern in California. Prepared by Department of Wildlife and Fisheries Biology, University of California, Davis for California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova.

Munday, P. L., D. L. Dixson, J. M. Donelson, G. P. Jones, M. S. Pratchett, G. V. Devitsina, K. B. Døving. 2009. Ocean acidification impairs olfactory discrimination and homing ability of a marine fish. Proceedings of the National Academy of Sciences of the United States of America. 106(6):1848–52.

Formatted: Swedish (Sweden)

Murphy, M. L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and Alaska- requirements for protection and restoration. National Oceanic and Atmospheric Administration, NOAA Coastal Ocean Program, Decision Analysis Series No. 7.

Myers, J. M., R. G. Kope, G. J. Bryant, D. Teel, L. J. Lierheimer, T. C. Wainwright, W. S. Grant, F. W. Waknitz, K. Neeley, 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.

Naish, K. A., J. E. Taylor III, P. S. Levin, T. P. Quinn, J. R. Winton, D. Huppert, and R. Hilborn. 2007. An evaluation of the effects of conservation and fishery enhancement hatcheries on wild populations of salmon. Advances in Marine Biology 53:61–194.

National Marine Fisheries Service. (NMFS). 1997. Investigation of scientific information on the impacts of California sea lions and Pacific harbor seals on salmonids and on the coastal ecosystems of Washington, Oregon, and California. U.S Department of Commerce, NOAA Technical Memorandum NOAA-NWFSC-28. Accessed at https://www.krisweb.com/biblio/gen_nmfs_nmfs_1997_tm28.pdf

National Marine Fisheries Service (NMFS). 2010. Biological opinion on the operation of the Klamath Project between 2010 and 2018. Prepared for Bureau of Reclamation by NOAA Fisheries Service, Southwest Region. Available at: http://swr.nmfs.noaa.gov/klamath/FINALKlamath_Ops_031510.pdf

National Marine Fisheries Service. (NMFS). 2013. Biological Opinion on the Effects of Proposed Klamath Project Operations from May 31, 2013, through March 31, 2023, on Five Federally Listed Threatened and Endangered Species. West Coast Regional Office ESA Section 7 Consultation.

National Marine Fisheries Service. (NMFS). 2014. Final Recovery Plan for the southern Oregon/northern California coast Evolutionarily Significant Unit of Coho Salmon (*Oncorhynchus kisutch*). National Marine Fisheries Service. Arcata, California. Accessed at: https://repository.library.noaa.gov/view/noaa/15985

National Marine Fisheries Service. (NMFS). 2018. National Oceanic and Atmospheric Administration, February 27, 2018. Endangered and Threatened Wildlife; 90-Day Finding on a petition to list Chinook Salmon in the Upper Klamath/Trinity rivers basin as threatened or endangered under the Endangered Species Act

National Marine Fisheries Service. (NMFS). 2019. Ecosystem Status Report of the California Current for 2019: A summary of ecosystem indicators compiled by the California Current

Integrated Ecosystem Assessment Team (CCIEA). Accessed at: https://repository.library.noaa.gov/view/noaa/22658

National Research Council of the National Academies (NRC). 2004. Endangered and threatened fishes in the Klamath River basin. National Academies Press. Washington, D.C.

National Research Council of the National Academies (NRC). 2006. Surface temperature reconstructions for the last 2,000 years. National Academy Press, Washington, D.C.

National Research Council of the National Academies (NRC). 2008. Hydrology, ecology, and fishes of the Klamath River basin. National Academies Press. Washington, D.C.

Neave, F. 1943. Diurnal fluctuations in the upstream migration of Coho and spring salmon. Journal of Fisheries Research Board of Canada 6:158-163.

Nei, M. 1987. Molecular evolutionary genetics. Columbia University Press. New York.

Nichols, K., and J. S. Foott. 2005. Health monitoring of juvenile Klamath River Chinook Salmon, FY 2004 Investigational Report. USFWS California-Nevada Fish Health Center, Anderson, CA.

North Coast Regional Water Quality Control Board (NCRWQCB). 2005. Total Maximum Daily Load for Temperature and Implementation Plan, Salmon River, Siskiyou County, California. Accessed at: https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/Salmon_river/062405/part_1_Salmon_temperature_tmdl_report_adopted.pdf

O'Farrell, M., S. Allen-Moran, K. Atkinson, P. Dygert, S. Gallagher, A. Grover, B. Kormos, M. Lacy, E. Larson, M. Mohr, S. Ricker, W. Satterthwaite, and B. Spence. 2015. California coastal Chinook Salmon fishery management: future prospects. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-542

O'Farrell, M. R., M. L. Palmer-Zwahlen, and J. M. Simon. 2010. Is the September 1 river return date approximation appropriate for Klamath River fall Chinook? NOAA-TM-NMFS-SWFSC-468.

Olson, A. 1996. Freshwater rearing strategies of spring Chinook Salmon *(Oncorhynchus tshawytscha*) in Salmon River tributaries, Klamath Basin, California. Master's thesis. Humboldt State University, Arcata, California.

Oregon Department of Fish and Wildlife (ODFW). 2008. A plan for the reintroduction of anadromous fish in the Upper Klamath Basin. Salem, Oregon.

Formatted: German (Germany)

Commented [SC129]: Font here and elsewhere in the lit cited section.

Oregon Department of Fish and Wildlife (ODFW) and The Klamath Tribes. 2019. Draft Implementation plan for the reintroduction of anadromous fishes into the Oregon portion of the Upper Klamath Basin. 03-01-2019 Draft. Oregon Department of Fish and Wildlife.

Ou, M., T. J. Hamilton, J. Eom, E. M. Lyall, J. Gallup, A. Jiang, J. Lee, D. A. Close, Y. Sang-Seon, C. J. Brauner. 2015. Responses of pink salmon to CO_2-induced aquatic acidification. Nature Climate Change. 2015; 5(10).

Pacific Fishery Management Council (PFMC). 2016. Pacific Coast Salmon Fishery Management Plan for commercial and recreational salmon fisheries off the coasts of Washington, Oregon, and California as amended through Amendment 19. PFMC, Portland, OR.

Pacific Fishery Management Council (PFMC). 2019. Salmon rebuilding plan for Sacramento River fall Chinook draft 12. Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon.

Pacific Watershed Associates (PWA). 1994. Action Plan for restoration of the South Fork Trinity River watershed and its fisheries. Prepared for the US Bureau of Reclamation and the Trinity River Task Force. Accessed at: http://www.krisweb.com/biblio/sft_usbor_pwa_1994_sftplan/pwa1.htm

Page, L. M., and B. M. Burr. 1991. A field guide to freshwater fishes: North America north of Mexico. Volume 42 of Peterson field guide series. Houghton Mifflin.

Pearse, D. E. 2016. Saving the spandrels? Adaptive genomic variation in conservation and fisheries management. Journal of Fish Biology 89(6):2697-2716.

Peterson, W.T., J. L. Fisher, C. A. Morgan, S. M. Zeman, B. J. Burke, and K. M. Jacobson. 2018. Ocean ecosystem indicators of salmon marine survival in the northern California Current. https://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/documents/Peterson_et_al_2018_revised.pdf.

Platts, W. S., M. A. Shirazi, and D. H. Lewis. 1979. Sediment particle sizes used by salmon for spawning with methods for evaluation. Report EPA 600/3-79-043, U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR.

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(8)e1603198.

Reiser, D. W., and T. C. Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in western North America: Habitat requirements of anadromous salmonids. USDA Forest Service Anadromous Fish Habitat Program, Portland, OR. USDA Forest Service General Technical Report PNW-96. Accessed at: https://www.fs.fed.us/pnw/pubs/journals/pnw_1979_reiser001.pdf

Riddell, B., R. D. Brodeur, A. V. Bugaev, P. Moran, J. Murphy, J. A. Orsi, M. Trudel, L. A. Weitkamp, B. K. Wells, and A. C. Wertheimer. 2018. Ocean ecology of Chinook Salmon. In R.J. Beamish, editor. Ocean Ecology of Pacific salmon and Trout, Chapter 5. American Fisheries Society.

Rupert, D. L., S. A. Gough, N. A. Som, N. J. Davids, W. C. Matilton, A. M. Hill, and J. L. Pabich. 2017. Mainstem Trinity River Chinook Salmon Spawning Survey, 2015 and 2016. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Report Number DS 2017–56, Arcata, California.

Sartori, J. C. 2006. Comparative otolith microstructural analysis of adult, juvenile, and fry life stages of Salmon River spring Chinook salmon of northwestern California. Technical report. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California.

Satterthwaite, W. H., and M.R. O'Farrell. 2018. Inferred ocean distributions of genetically similar Chinook Salmon stocks compared across run timing and river/hatchery of origin. Fisheries Research 199:171-176.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

Shafer, A. B. A., J. B. W. Wolf, P. C. Alves, L. Bergström, M. W. Bruford, I. Brännström, G. Colling, L. Dalén, L. De Meester, R. Ekblom, K. D. Fawcett, S. Fior, M. Hajibabaei, J. A. Hill, A. R. Hoezel, J. Höglund, E. L. Jensen, J. Krause, T. N. Kristensen, M. Krützen, J. K. McKay, A. J. Norman, R. Ogden, E. M. Österling, N. J. Ouborg, J. Piccolo, D. Popović, C. R. Primmer, F. A. Reed, M. Roumet, J. Salmona, T. Schenekar, M. K. Schwartz, G. Segelbacher, H. Senn, J. Thaulow, M. Valtonen, A. Veale, P. Vergeer, N. Vijay, C. Vilà, M. Weissensteiner, L. Wennerström, C. W. Wheat, and P. Zieliński. 2015. Genomics and the challenging translation into conservation practice. Trends in Ecology and Evolution 30:78–87.

Shaw, T. A., C. Jackson, D. Nehler, and M. Marshall. 1997. Klamath River (Iron Gate Dam to Seiad Creek) life stage periodicities for Chinook, Coho, and steelhead. Prepared by U.S. Fish and Wildlife Service, Coastal California Fish and Wildlife Office, Arcata, California.

Scheiff, A. J., J. S. Lang, and W. D. Pinnix. 2001. Juvenile salmonid monitoring on the mainstem Klamath River at Big Bar and mainstem Trinity River at Willow Creek 1997-2000. Annual report of the Klamath River Fisheries Assessment Program. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California

Shumway, D. L., C. E. Warren, and P. Duodoroff. 1964. Influence of oxygen concentration and water movement on the growth of steelhead trout and Coho Salmon embryos. Transactions of the American Fisheries Society 93(4):342-356.

Snyder, J. O. 1931. Salmon of the Klamath River, California. Division of Fish and Game of California, Sacramento. Fish Bulletin No. 34.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook Salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325-333.

Soto, T., M. Hentz, and W. Harling. 2008. Mid-Klamath Subbasin Fisheries Resources Recovery Plan. Final Draft. USFWS, Yreka, CA. Original 2003. Updated 2008.

Stanford, J., W. Duffy, E. Asarian, B. Cluer, P. Detrich, L. Eberle, S. Edmondson, S. Foot, M. Hampton, J. Kann, K. Malone, and P. Moyle. 2011. Conceptual model for restoration of the Klamath River. In L. Thorsteinson, S. VanderKooi, and W. Duffy, eds. 2011. Proceedings of the Klamath Basin Science Conference, Medford, Oregon, February 1-5, 2010: U.S. Geological Survey Open File Report 2011-1196.

Stanley, W. T., and K. E. Shaffer. 1995. Harbor seal (*Phoca vitulina*) predation on seined salmonids in the lower Klamath River, California. Marine Mammal Science 11(3):376-385.

Stearley, R. F., and G. R. Smith. 1993. Phylogeny of the Pacific trouts and salmons (*Oncorhynchus)* and genera of the Family Salmonidae. Transactions of the American Fisheries Society 122(1):1-33.

Stillwater Sciences. 2009. Effects of sediment release following dam removal on the aquatic biota of the Klamath River. Technical Report. Prepared by Stillwater Sciences, Arcata, California for State Coastal Conservancy, Oakland, California. Available at: http://www.Reclamation.gov/mp/kbao/kbra/docs/other/Klamath%20Dam%20Removal%20Biological%20Analysis_FINAL.pdf.

Stillwater Sciences. 2018. Salmon River Floodplain Habitat Enhancement and Mine Tailing Remediation Project. Phase 1: Technical Analysis of Opportunities and Constraints. Technical Memorandum prepared for Salmon River Restoration Council. January 2018. Accessed at: http://srrc.org/publications/programs/habitatrestoration/Salmon%20River%20Floodplain%20Enhancement%20Tech%20Memo_Final%202018.pdf

Stocking, R. W., and J. L. Bartholomew. 2004. Assessing links between water quality, river health and ceratomyxosis of salmonids in the Klamath River system. Department of Microbiology, Oregon State University, Corvallis, OR.

Sullivan, C. M., 1989. Juvenile life-history and age composition of mature fall Chinook salmon returning to the Klamath River, 1984-1986. Master's Thesis. Humboldt State University, Arcata, California.

Sullivan, R. M., and J. P. Hileman. 2019. Effects of managed flows on Chinook *Salmon (Oncorhynchus tshawytscha)* in relation to run-timing, fertility, and fluctuations in water temperature and flow volume. California Fish and Game 105(3):132-176; 2019.

Strange, J. S. 2010. Summary of scientific evidence to guide special flow releases to reduce the risk of adult fall Chinook Salmon mass disease mortality in the Lower Klamath River. Yurok Tribal Fisheries Program. Klamath, CA.

Strange, J. S. 2012. Migration strategies of adult Chinook Salmon runs in response to diverse environmental conditions in the Klamath River basin, Transactions of the American Fisheries Society 141(6)1622-1636.

Suckley, G. 1861. Notices of certain new species of North American Salmonidae from the north-west coast of America. Annals of the Lyceum of Natural History (New York) 7:306-313.

SWRCB (California State Water Resources Control Board). 2018. Draft Environmental Impact Report for the Lower Klamath Project License Surrender Volume I. State Clearinghouse No. 2016122047. Prepared by Stillwater Sciences, Berkeley, CA.

Thom, B. 2020. Letter to Phil Anderson, Chair, Pacific Fishery Management Council. Supplemental NMFS Report 1. March 2020.

Thomas, A. E., J. L. Banks, and D. C. Greenland. 1969. Effect of yolk sac absorption on the swimming ability of fall Chinook Salmon. Transactions of the American Fisheries Society. 1968(3):406-410.

Thomas, V. G. 1985. Experimentally determined impacts of a small, suction gold dredge on a Montana stream. North American Journal of Fisheries Management 5:480-488.

Thomas, W., R. E. Withler, and A. T. Beckenbach. 1986. Mitochondria! DNA analysis of Pacific salmonid evolution. Canadian Journal of Zoology 64:1058-1064.

Thompson, T. Q., M. R. Bellinger, S. M. O'Rourke, D. J. Prince, A. E. Stevenson, A. T. Rodrigues, M. R. Sloat, C. F. Speller, D. Y. Yang, V. L. Butler, M. A. Banks, and M. R. Miller. 2019. Anthropogenic habitat alteration leads to rapid loss of adaptive variation and restoration potential in wild Salmon populations. Proceedings of the National Academy of Science 116(1):177-186.

Thorsteinson, L., S. VanderKooi, and W. Duffy, editors. 2011. Proceedings of the Klamath Basin Science Conference, Medford, Oregon, February 1–5, 2010: U.S. Geological Survey Open-File Report 2011-1196.

Torgersen, C. E., D. M. Price, H. W. Li, and B. A. McIntosh. 1999. Multiscale thermal refugia and stream habitat associations of Chinook Salmon in northeastern Oregon. Ecological Applications 9(1):301-319.

Troxel, D. 2018. 2018 spring Chinook Salmon creel survey on the Lower Klamath River. California Department of Fish and Wildlife. Northern Region. Klamath River Project.

U.S. Department of Interior (USDI). 2000. Record of decision, Trinity River mainstem fishery restoration final environmental impact statement/environmental impact report. U.S. Department of Interior, Washington D.C.

U.S. Department of Interior (USDI). 2012. Klamath Facilities Removal Final Environmental Impact Statement/Environmental Impact Report. United States Department of Interior.

U.S. Fish and Wildlife Service (USFWS) and Hoopa Valley Tribe. 1999. Trinity River Flow Evaluation. Final Report. A report to the Secretary of the Interior. Accessed at: https://www.trrp.net/library/document/?id=226

U.S. Fish and Wildlife Service (USFWS). 2000. Record of Decision, Trinity River Mainstem Fishery Restoration, Final Environmental Impact Statement/Environmental Impact Report, U.S. Department of the Interior, Washington, DC. Accessed at: https://www.trrp.net/library/document/?id=227

U.S. Fish and Wildlife Service (USFWS). 2003. Klamath River fish die-off September 2002: Causative factors of mortality. Report Number AFWO-F-02-03. November 7, 2003.

U.S. Fish and Wildlife Service and California Department of Fish and Game (USFWS/CDFG). 1956. A Plan for the Protection and Maintenance of Fish and Wildlife Resources Affected by the Trinity River Division, Central Valley Project. Prepared jointly by United States Fish and Wildlife Service and the California Department of Fish and Game. November 1956.

U.S. Forest Service (USFS). 1996. Fish theme name: “Fish Species Range” (knf_fish). Survey data courtesy of USDA Forest Service, Klamath National Forest, KNF Supervisor’s Office, Yreka, California. Data downloaded on August 24, 2005. As cited in Carter, K., and S. Kirk. 2008. Fish and fishery resources of the Klamath River basin. 2008. Appendix 5 *in* North Coast Regional Water Quality Control Board. 2010. Final staff report for the Klamath River Total Maximum Daily Loads (TMDLs) addressing temperature, dissolved oxygen, nutrient, and microcystin impairments in California. The proposed site-specific dissolved oxygen objectives for the Klamath River in California and the Klamath River and Lost River

Implementation plans. California Water Boards, North Coast Region, Santa Rosa, CA. Accessed at: https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/klamath_river/

U.S. Forest Service (USFS). 2006. Review comments, Klamath TMDL ReportFish Population distribution map. Letter dated July 7, 2006. Klamath National Forest, 2 pp. As cited in Carter, K., and S. Kirk. 2008. Fish and fishery resources of the Klamath River basin. 2008. Appendix 5 *in* North Coast Regional Water Quality Control Board. 2010. Final staff report for the Klamath River Total Maximum Daily Loads (TMDLs) addressing temperature, dissolved oxygen, nutrient, and microcystin impairments in California. The proposed site-specific dissolved oxygen objectives for the Klamath River in California and the Klamath River and Lost River Implementation plans. California Water Boards, North Coast Region, Santa Rosa, CA. Accessed at: https://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/klamath_river/

U.S. Global Change Research Program (USGCRP). 2009. T. R. Karl, J. M. Melillo, and T. C. Peterson, editors. Global Climate Change Impacts in the United States. Cambridge University Press.

U.S. Global Change Research Program (USGCRP). 2017. Wuebbles, D. J., D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, and T. K. Maycock, editors. Climate Science Special Report: Fourth National Climate Assessment, Volume I U.S. Global Change Research Program, Washington, DC, USA,

Upton, H. F. 2010. Commercial fishery disaster assistance. Congressional Research Service. RL34209.

Walbaum, J. J. 1792. Petri Artedi renovati: bibliotheca Vet philosophia ichlhyologica. Ichthyologiae, pars III. A. F. Roese, Grypeswaldiae.

Wales, J. H. 1951. “The decline of the Shasta River king salmon run.” California Department of Fish and Game.

Waples, R. S. 1991a. Pacific salmon, *Oncorhynchus* spp., and the definition of “species” under the endangered species act. Marine Fisheries Review 53:11–22.

Waples, R. S. 1991b. Genetic interactions Between Hatchery and Wild Salmonids: Lessons from the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences. 48:124-133.

Waples R. S. 1995. Evolutionarily significant units and the conservation of biological diversity under the Endangered Species Act. Pages 8—27 in J.L. Nielsen and G.A. Powers, editors. Evolution and the aquatic ecosystem: Defining unique units in population conservation. Symposium 17. American Fisheries Society, Bethesda, Maryland.

Waples, R. S. 1999. Dispelling some myths about hatcheries. Fisheries 24(2):12–21

Waples, R. S. 2006. Distinct population segments. Pages 127–149 in J. M. Scott, D.D. Goble, and F. W. Davis. The Endangered Species Act at thirty: Conserving biodiversity in human-dominated landscapes. Island Press, Washington, DC.

Waples, R. S., and S. T. Lindley. 2018. Genomics and conservation units: The genetic basis of adult migration timing in Pacific salmonids. Evolutionary Applications 11:1518-1526.

Waples, R. S., K. A. Naish, and C. R. Primmer. 2020. Conservation and Management of salmon in the age of genomics. Annu. Rev. Anim. Biosci. 8:117–143.

Waples, R. S., D. J. Teel, J. M. Myers, and A. R. Marshall. 2004. Life-history divergence in Chinook Salmon: historic contingency and parallel evolution. Evolution 58:386-403.

Wedemeyer, Gary A. [Ed] 2001. Fish hatchery management, second edition. American Fisheries Society, Bethesda MD, 733 pp.

Wells, B. K., J. A. Santora, J. C. Field, R. B. MacFarlane, B. B. Marinovic, W. J. Sydeman. 2012. Population dynamics of Chinook salmon *Oncorhynchus tshawytscha* relative to prey availability in the central California coastal region. Mar Ecol Prog Ser. 457:125–37. https://doi.org/10.3354/meps09727

West, J. R. 1991. A proposed strategy to recover endemic spring-run Chinook Salmon populations and their habitats in the Klamath River Basin. USDA-Forest Service. Klamath National Forest.

Williams, J. G. 2006. Central Valley salmon: a perspective on Chinook and steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science 4(3).

Williams, T. H., S. T. Lindley, B. C. Spence, D. A. Boughton. 2011. Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act: Southwest. 20 May 2011 – Update to 5 January 2011 report. National Marine Fisheries Service, Southwest Fisheries Science Center, Fisheries Ecology Division,110 Shaffer Road, Santa Cruz, California 95060

Williams, T. H., J. C. Garza, N. J. Hetrick, S. T. Lindley, M. S. Mohr, J. M. Myers, M. R. O'Farrell, R. M. Quinones, and D. J. Teel. 2013. Upper Klamath and Trinity River Chinook Salmon Biological Review Team Report. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-502.

Williamson, K., and D. Hillemeier. 2001. An assessment of pinniped predation upon fall-run Chinook Salmon in the Klamath River Estuary, CA, 1998. Yurok Tribal Fisheries Program.

Klamath, CA. Accessed at: http://www.yuroktribe.org/departments/fisheries/documents/98Finalbwpin_pred_WILLIAMSON.pdf

Wydoski, R. S., and R. R. Whitney. 1979. Inland fishes of Washington. University of Washington Press. Seattle, Washington.

Appendices

Appendix A. California Hatchery Scientific Review Group Recommendations for Trinity River and Iron Gate Hatchery Chinook Salmon Artificial Propagation Programs

Following are the recommendations of the CA HSRG (2012) for Trinity River Hatchery Chinook Salmon programs. Some, but not all, of these recommendations have been implemented.

Recommendations for all Trinity River Hatchery Programs:

a) Natural-origin fish should be incorporated into broodstock at a minimum rate of 10% to prevent divergence of the hatchery and natural components of the integrated population.
b) Adult holding facilities should be upgraded/expanded to provide adequate space, water flows and temperatures to hold the number of adults required for broodstock at high rates of survival (more than 90%). Facilities need to be adequate to hold the expected number of unripe adults for extended periods with minimal hatchery-caused mortality.
c) The adult spawning facility is inadequate to meet current needs for fish sorting, spawning and monitoring and should be upgraded.
d) Investigate the feasibility of collecting natural-origin adult fish at alternate locations. The existing trapping location is very limited in its ability to capture fish representing the entire spectrum of life-history diversity. Only fish that migrate to the furthest upstream reaches are susceptible to capture.
e) Performance standards for each phase of the fish culture process should be established and tracked annually. Summaries of data collected with comparisons to established targets must be included in annual hatchery reports.
f) A Monitoring and Evaluation Program should be developed and implemented, and a Hatchery Coordination Team formed for the program.
g) Co-managers should develop and promulgate a formal, written fish health policy for the operation of the hatchery. Hatchery compliance with this policy should be documented annually as part of a Fish Health Management Plan. The current fish health policy is inadequate to protect native stocks.
h) Co-managers should develop an updated Hatchery Procedure Manual that includes performance criteria and culture techniques described in IHOT (1995), Fish Hatchery Management (Wedemeyer 2001), or comparable publications. The fish culture manual in current use (Leitritz and Lewis 1976) is outdated and does not reflect current research and advancements in fish culture.
i) Adult collection facilities should be operated throughout the entire temporal migration period of the run and should not exclude fish with particular life history characteristics, except when non-representative broodstock collection is necessary to achieve program goals. Currently, the trap is shut down for a period of approximately two weeks to

minimize hybridization between separate spring and fall Chinook Salmon. Fish collected during this period should be euthanized without spawning.

j) Tag analysis should be used to determine the number of spring and fall Chinook Salmon spawned during the suspected period of run overlap (e.g., fish spawned in the last two weeks of spring and the first two weeks of fall). Tags should be read and egg lots tracked and eliminated from production as appropriate to reduce introgression of the two runs. Incubation techniques should therefore allow for separation of eggs from individual parents/families (no more than two families per tray).
k) Program fish should be 100% coded-wire tagged and 25% adipose fin-clipped (as suggested in other sections of CA HSRG (2012)). Yearling releases should receive an additional distinguishing external mark or tag (e.g., a ventral fin clip) allowing real-time discrimination from fingerling releases at the adult stage.
l) Returning yearling-program origin adults should not be used as broodstock. If eggs are collected from or fertilized by such fish, they should be culled soon after spawning. Adequate numbers of fingerlings should be released each year to meet numerical goals for broodstock. When adult returns from fingerling releases are inadequate to satisfy hatchery egg take needs, yearling returns may be used to make up this deficit.
m) CWT releases and recoveries of fall Chinook should be reported annually to RMIS in a timely manner.
n) Jacks should be incorporated into the broodstock at a rate that does not exceed 50% of the total number of jacks encountered during spawning operations and in no case more than 5% of the total males spawned.
o) Fish growth trajectories need to be monitored more closely to achieve the identified release target of 90 fpp for fingerlings and 10 fpp for yearlings. Data supplied by the hatchery indicate that average release size for the two respective groups has been 108 fpp and 15.4 fpp from 2000 – 2010.

Major Program Recommendations Specific to the Trinity River Hatchery Fall Chinook Salmon Program:

a) Adult collection facilities should be operated throughout the entire temporal migration period of the run and should not exclude fish with particular life history characteristics, except when non-representative broodstock collection is necessary to achieve program goals. Currently, the trap is shut down for a period of approximately two weeks to minimize hybridization between separate spring and fall Chinook Salmon. Fish collected during this period should be euthanized without spawning.
b) Tag analysis should be used to determine the number of spring and fall Chinook Salmon spawned during the suspected period of run overlap (e.g., fish spawned in the last two weeks of spring spawning and the first two weeks of fall spawning). Tags should be read and egg lots tracked and eliminated from production as appropriate to reduce

introgression of the two runs. Incubation techniques should therefore allow for separation of eggs from individual parents/families (no more than two families per tray).

c) Program fish should be 100% coded-wire tagged and 25% adipose fin-clipped. “Yearling” releases should receive an additional distinguishing external mark or tag (e.g., a ventral fin clip) allowing real-time discrimination from fingerling releases at the adult stage.
d) Returning yearling-origin adults should not be used as broodstock. If eggs are collected from or fertilized by such fish, they should be culled soon after spawning. Adequate numbers of fingerlings should be released each year to meet numerical goals for broodstock. When adult returns from fingerling releases are inadequate to satisfy hatchery egg take needs, yearling returns may be used to make up this deficit.
e) CWT releases and recoveries of fall Chinook Salmon should be reported annually to RMIS in a timely manner.
f) Jacks should be incorporated into the broodstock at a rate that does not exceed 50% of the total number of jacks encountered during spawning operations and in no case more than 5% of the total males spawned.
g) Fish growth trajectories need to be monitored more closely to achieve the identified release target of 90 fpp for fingerlings and 10 fpp for yearlings. Data supplied by the hatchery indicate that average release size for the two respective groups has been 108 fpp and 15.4 fpp from 2000 – 2010.

Major Program Recommendations Specific to the Trinity River Hatchery Spring Chinook Salmon Program:

a) Adult collection facilities should be operated throughout the entire time period of the migration and should not exclude fish with particular life history characteristics, except when non-representative broodstock collection is necessary to achieve program goals. Currently, the trap is shut down for a period of approximately two weeks to minimize hybridization between separate spring and fall Chinook Salmon. Fish collected during this period should be euthanized without spawning.
b) Tag analysis should be used to determine the number of spring and fall Chinook Salmon spawned during the suspected period of run overlap (e.g., fish spawned in the last two weeks of spring and the first two weeks of fall). Tags should be read and egg lots tracked and eliminated from production as appropriate to reduce introgression of the two runs. Incubation techniques should therefore allow for separation of eggs from individual parents/families (no more than two families per tray).
c) Program fish should be 100% coded wire tagged and 25% adipose fin-clipped. “Yearling” releases should receive an additional distinguishing external mark or tag (e.g., a ventral fin clip) allowing real-time discrimination from fingerling releases at the adult stage.
d) Returning yearling-origin adults should not be used as broodstock. If eggs are collected from or fertilized by such fish, they should be culled soon after spawning. Adequate numbers of fingerlings should be released each year to meet numerical goals for

broodstock. When adult returns from fingerling releases are inadequate to satisfy hatchery egg take needs, yearling returns may be used to make up this deficit.

e) CWT releases and recoveries of spring (and fall) Chinook Salmon should be reported annually to RMIS in a timely manner.
f) Jacks should be incorporated into the broodstock at a rate that does not exceed 50% of the total number of jacks encountered during spawning operations and in no case more than 5% of the total males spawned.
g) Fish growth trajectories need to be monitored more closely to achieve the identified release target of 90 fpp for fingerlings and 10 fpp for yearlings.

Following are the recommendations of the CA HSRG (2012) for Iron Gate Hatchery Chinook Salmon programs. Some, but not all, of these recommendations have been implemented. If the Dam Removal project on the Klamath River goes into effect, IGH will no longer be functional resulting in many of the following recommendations becoming irrelevant.

Recommendations for all Iron Gate Hatchery Programs:

a) Clear goals should be established for the program. Program production goals should be expressed in terms of the number of age-3 ocean recruits just prior to harvest (Chinook Salmon), age-3 adults returning to freshwater (Coho Salmon), and the number of adults and half-pounders returning to freshwater (steelhead).
b) Adult holding facilities in hatcheries should be upgraded/expanded to provide adequate space, water flows and temperature regimes to hold the number of adults required for broodstock at high rates of survival (greater than 90%). Facilities need to be adequate to hold the expected number of unripe adults for extended periods with minimal hatchery-caused mortality.
c) The adult spawning facility is inadequate to meet current needs for fish sorting, spawning and monitoring and should be upgraded.
d) All outdoor raceways should be protected from predators with bird netting or similar protection to reduce predation rates on juvenile fish.
e) Managers should investigate the feasibility of collecting natural-origin adult fish at alternate locations. The existing trapping location is very limited in its ability to capture fish representing the entire spectrum of life history diversity. Only fish that migrate to the furthest upstream reaches are susceptible to capture.
f) Performance standards for each phase of the fish culture process should be established and tracked annually. Summaries of data collected with comparisons to established targets must be included in annual hatchery reports.
g) CDFG should develop and promulgate a formal, written fish health policy for operation of its anadromous hatcheries through the Fish and Game Commission policy review process. Hatchery compliance with this policy should be documented annually as part of a Fish Health Management Plan. The current CDFG fish health policy is inadequate to protect native stocks.

h) CDFG should develop an updated Hatchery Procedure Manual which includes performance criteria and culture techniques presented in IHOT (1995), Fish Hatchery Management (Wedemeyer 2001) or comparable publications. The fish culture manual (Leitritz and Lewis 1976) is outdated and does not reflect current research and advancements in fish culture.

i) A Monitoring and Evaluation Program should be developed and implemented and a Hatchery Coordination Team formed for the program. Implementation of these processes will inform hatchery decisions and document compliance with best management practices defined in this report.

Major Program Recommendations Specific to the Iron Gate Hatchery Fall Chinook Salmon Program:

a) Managers should consider changes in the program, including reducing the size of the program, to mitigate disease issues. Large numbers of naturally spawning fish may increase the incidence of *C. shasta* disease through the release of myxospores from carcasses, which in turn increases the probability of perpetuating myxozoan infections in juvenile Chinook Salmon and Coho Salmon in the following spring and summer. We note that in any situation where program size is reduced or programs eliminated, in no case should such change result in relinquishment of mitigation responsibility.

b) Natural-origin fish should be incorporated into broodstock at a minimum rate of 10% to prevent divergence of the hatchery and natural components of the integrated population. This may require auxiliary adult collection facilities (e.g., Bogus Creek) or alternative collection methods (e.g., seining or trapping).

c) Jacks should be incorporated into the broodstock at a rate that does not exceed 50% of the total number of jacks encountered during spawning operations and in no case more than 5% of the total males spawned.

d) Program fish should be 100% coded-wire tagged and 25% adipose fin-clipped. “Yearling” releases should receive an additional distinguishing external mark or tag (e.g., a ventral fin clip) allowing real-time discrimination from fingerling releases at the adult stage. Returning yearling-origin adults should not be used as broodstock. If eggs are collected from or fertilized by such fish, they should be culled soon after spawning. Adequate numbers of fingerlings should be released each year to meet numerical goals for broodstock. When adult returns from fingerling releases are inadequate to satisfy hatchery egg take needs, yearling returns may be used to make up this deficit.

e) CWT releases and recoveries of fall Chinook Salmon should be reported annually to RMIS in a timely manner.

f) Water quality for egg incubation should be improved to remove organic debris and siltation that is likely affecting egg survival. If the air incubation solution tried in 2011 is ineffective, hatchery and fish health staff should continue studies to determine the cause of low egg survival rates.

Appendix B. Methods Used to Evaluate Ocean Fishery Harvest

The department evaluated ocean fishery harvest using marked and tagged TRH hatchery-origin UKTR spring Chinook Salmon as a surrogate for all UKTR Spring Chinook Salmon. Individual CWT codes were identified as UKTR spring Chinook Salmon using the species, run type, and hatchery location. Recoveries were expanded for the proportion of total released fish with CWTs and adipose fin-clips and sample rate (the proportion of the fishery by time and area that was observed). Results were summarized by ocean salmon fishery management area as described in the Pacific Fishery Management Council's Salmon Fishery Management Plan (FMP).

Because of inconsistent, and in some cases low, interannual CWT tag and mark rates, UKTR spring Chinook Salmon recoveries prior to brood year 1995 were excluded from the analysis of fishery harvest, as were incomplete broods (i.e., 2013-2015). These exclusions left 1,596 recoveries available to evaluate ocean salmon fishery harvest by fishery type (i.e., commercial or recreational), time of year (monthly time-steps) and geographic location (i.e., FMP management area). These recoveries were available to ocean salmon fisheries from 1997 (brood year 1995 age-2) through 2017 (brood year 2012 age-5). No UKTR spring Chinook Salmon younger than age-2 or older than age-5 were encountered from these broods[16].

To conduct this analysis, CWTs are extracted and decoded in a laboratory, merged with data from ocean salmon harvest and fishing effort, including the proportion of the fishery that was observed, and are made publicly available through the Regional Mark Information System (www.rmpc.org). These fishery recoveries combined with hatchery release information, including the proportion of released fish marked with an adipose fin-clip and tagged with CWTs, can be used to estimate total harvest of a particular stock at various levels of temporal and geographic stratification and by fishery type. While Genetic Stock Identification (GSI) can sometimes be used to identify stocks in mixed stock fisheries, standard GSI techniques cannot distinguish UKTR spring Chinook Salmon from UKTR fall Chinook Salmon because they are not genetically distinct. In addition, existing GSI samples are very limited in quantity and in temporal and spatial coverage.

Trinity River Hatchery has released CWT tagged UKTR spring Chinook Salmon annually since at least 1976 (Table 6.14 in report); however, prior to 1995 there is considerable interannual variation in the total number of fish released and the proportion tagged. For example, a little over 35,000 UKTR spring Chinook Salmon were released at a 98% CWT tag rate in 1980 followed by over 1.6 million released at a 17% tag rate the following year. Inconsistent and relatively low tag rates confound fishery harvest analyses, particularly when overall recoveries are few and fishing seasons by design vary between years in time and space to protect vulnerable stocks

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[16] One age-6 UKTR Spring Chinook was encountered in 1988 (brood year 1982) in the Coos Bay commercial ocean salmon fishery.

(i.e., weak-stock management). This variation leads to unreliable results, and likely over- or under-estimation of actual harvest. Since 1995, an average of 1.4 million UKTR spring Chinook Salmon have been released from TRH with an average 23% CWT tag rate, reducing variability in inter-annual comparisons of UKTR spring Chinook Salmon harvest by ocean salmon fisheries (Table 4.1).

To account for varying fishing opportunity and relative abundance of other stocks, and to evaluate the times and areas where hatchery-origin UKTR spring Chinook Salmon were encountered in fisheries, the aggregate number of CWT recoveries expanded for hatchery production and sampling was scaled to the aggregate total harvest of all stocks by management area and month time-step.

Methods Used in Comparison of Hatchery-origin UKTR Spring and Fall Chinook Salmon Harvest Distribution in Ocean Salmon Fisheries

To determine whether management protections for Klamath River fall Chinook Salmon (KRFC; these are primarily UKTR fall Chinook Salmon but may also include a small number of fish from a different ESU; see *Section 6.11.1* for details) might apply to UKTR spring Chinook Salmon, this report compares the ocean spatial distribution of the UKTR spring and fall Chinook Salmon ecotypes[17]. Both ecotypes of the UKTR Chinook Salmon ESU have an annually marked and tagged hatchery component, allowing for differentiation of the ocean distribution of spring and fall TRH hatchery fish using tag recoveries in ocean salmon fisheries. Because fishery harvest is commonly used to evaluate ocean distribution of both natural and hatchery-origin salmon, the Department's analysis assumes that ocean harvest can be used as a proxy for ocean spatial distribution of both natural- and hatchery-origin fish. While this underlying assumption cannot be validated directly due to lack of fishery-independent data, fishery harvest is commonly used to evaluate probable ocean distribution of both natural- and hatchery-origin salmon. Also, inference of spatial patterns based on fishery interactions may in some cases be preferred from a management perspective over true spatial distribution. Because management actions are taken at the stock complex level, UKTR fall Chinook Salmon hatchery CWTs from both Iron Gate and Trinity River Hatcheries were used in this analysis. Data necessary to evaluate fishery impacts on natural-origin UKTR spring Chinook Salmon are currently unavailable due to lack of age-structured spawning return composition and cohort reconstructions. To ensure comparable metrics, only hatchery-origin UKTR fall Chinook Salmon (KRFC) were used for this comparison to UKTR spring Chinook Salmon ocean distribution and relative contribution.

Coded-wire tag and associated catch-sample and hatchery release information was downloaded from the Regional Mark Processing Center (www.rmpc.org) for brood years 1995 – 2012. In the commercial ocean salmon fishery 7,498 individual UKTR fall Chinook Salmon (KRFC)

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[17] See Section 7.4.6 for conclusions concerning protection afforded by existing regulations.

CWT recoveries and 1,596 TRH UKTR spring Chinook Salmon CWTs were used in this analysis. In the recreational ocean salmon fishery 1,547 UKTR fall Chinook Salmon (KRFC) CWTs and 297 TRH UKTR spring Chinook Salmon CWTs were used. Some open time-area-fisheries in the region over the period in this study had very few CWT recoveries, or none, from the 18 broods, while other time-area combinations are no longer available to ocean salmon fisheries because of regulation changes. For example, commercial ocean salmon fisheries south of Point Arena are currently closed in April to protect ESA Endangered Sacramento River winter Chinook Salmon, among others. Despite uncertainties introduced by low numbers of recoveries, all time-area combinations were retained in the analysis except recoveries north of Cape Falcon, Oregon (not shown). Recoveries north of this ocean salmon management boundary were excluded from the analysis due to the inability to apply management actions north of that location through state or federal regulatory mechanisms. The number of recreational ocean salmon fishery CWTs recovered from these stocks is generally low, especially in certain times and locations. Results based on times and areas with few recoveries should be interpreted with caution because no harvest of the stock was observed in most years within the analysis, and some seemingly higher levels of harvest may be influenced by a single or few years of sample data.

Each individual CWT recovery was expanded for its associated proportion of hatchery released Chinook that contained a CWT and the proportion of the fishery that was sampled, representing the hatchery component of UKTR fall Chinook Salmon (KRFC) and UKTR spring Chinook Salmon harvest in ocean salmon fisheries. The CWT harvest was then aggregated by stock, management area, and month time-step across all 18 broods.

While variation in total cumulative harvest could indicate variation in total harvest among times and areas, the results are complicated by total all-stocks harvest in that time-area and by interannual variation in fishing opportunity and fishing effort throughout the time period within a given time-area-fishery. For example, the commercial harvest of TRH UKTR spring Chinook Salmon is equally split between Oregon and California fisheries (see *Section 6 Factors Affecting the Ability to Survive and Reproduce*). However, the total all-stocks harvest is significantly higher in California and seasonal regulations between the states are inconsistent both between years and between management areas. UKTR fall Chinook Salmon (KRFC) and/or TRH UKTR spring Chinook Salmon from brood year 1995 would first be encountered in ocean salmon fisheries as age-2 fish in 1997, while these stocks would last be encountered as age-5 fish in 2000; however, very few age 5+ UKTR fall Chinook Salmon (KRFC) or TRH UKTR spring Chinook Salmon have been observed in ocean fisheries.

Fishing effort by fishery, management area and month is annually reported in the Review of Ocean Salmon Fisheries (www.pcouncil.org; Appendix A), and was summed across the 1997 through 2017 harvest years and intended to capture all age classes within the 1995 through 2012 brood years. Fish caught in the Oregon ocean waters commercial fishery, but ultimately landed in California prior to the practice's prohibition in 2005, was attributed to Oregon. Some Oregon state-water only commercial fisheries occur in December but are not shown; no UKTR fall Chinook Salmon (KRFC) or TRH UKTR spring Chinook Salmon have been observed in that fishery. Likewise, some recreational fisheries occurred in February in California but are not shown because no UKTR fall Chinook Salmon (KRFC) or TRH UKTR spring Chinook Salmon were harvested. Additionally, Coho salmon-only fishing effort (Oregon only) that could be determined was excluded for both commercial and recreational fisheries.

To account for variable fishing opportunity and resulting total fishing effort (i.e., the number of days fished), the catch per unit effort was determined by stock, fishery type, management area, and month. Again, this comparison might indicate variation in total harvest among times and areas; however, the relative abundance of the two ecotypes may not be directly comparable due to higher hatchery production of UKTR fall Chinook Salmon (both IGH and TRH origin). On average over 8.8 million UKTR fall Chinook Salmon are released from Iron Gate and Trinity River hatcheries (brood years 1995-2012), whereas 1.4 million UKTR spring Chinook Salmon are released annually from Trinity River Hatchery only. Lower abundance of UKTR spring Chinook Salmon hatchery stock could reasonably be expected to result in lower total harvest of that stock, and differences in harvest per day fished between the UKTR spring and fall Chinook Salmon ecotypes may not serve as an appropriate indicator of stock distribution.

To account for differences in overall hatchery abundance (as measured by total hatchery releases), the harvest per day fished (i.e., catch per unit effort or CPUE) was further scaled to the number of hatchery fish released by stock. This computation gives an index of ocean harvest per fishing effort per released Chinook Salmon (e.g., Satterthwaite and O'Farrell 2018, PFMC 2019, Lindley et al. 2009). Specifically, the Department analysis evaluated the expanded CWT recoveries per 100 days fished (commercial; 1,000 days fished for recreational) per 1 million released smolts.

Appendix C. General Form of Harvest Control Rules for Klamath and Sacramento River Fall Chinook Salmon Fishery Management

Figure 1 displays the form of harvest control rule used for both UKTR fall Chinook Salmon Sacramento River (SR) fall Chinook Salmon. The exploitation rate (F) is listed on the Y-axis and the pre-fishery ocean abundance in spawner equivalent units (N) is listed on the X-axis. Break points in the curve along the X-axis are calculated using biological concepts such as the Minimum Stock Size Threshold (MSST), the spawner escapement level expected to produce the maximum sustainable yield (S_{MSY}), and exploitation rate for acceptable biological catch (F_{ABC}). Break points are calculated as follows:

$A = MSST / 2$
$B = (MSST + S_{MSY}) / 2$
$C = S_{MSY} / (1 - 0.25)$
$D = S_{MSY} / (1 - F_{ABC})$

Along the Y-axis, the control rule sets a maximum fishery exploitation rate at F_{ABC}, which is the Maximum Fishery Mortality Threshold slightly reduced to allow for scientific uncertainty in abundance estimation methods. Exploitation rates decrease steadily with declining abundance forecast until two levels of *de minimis* fishery exploitation rates are reached at F = 0.25 and F = 0.10.

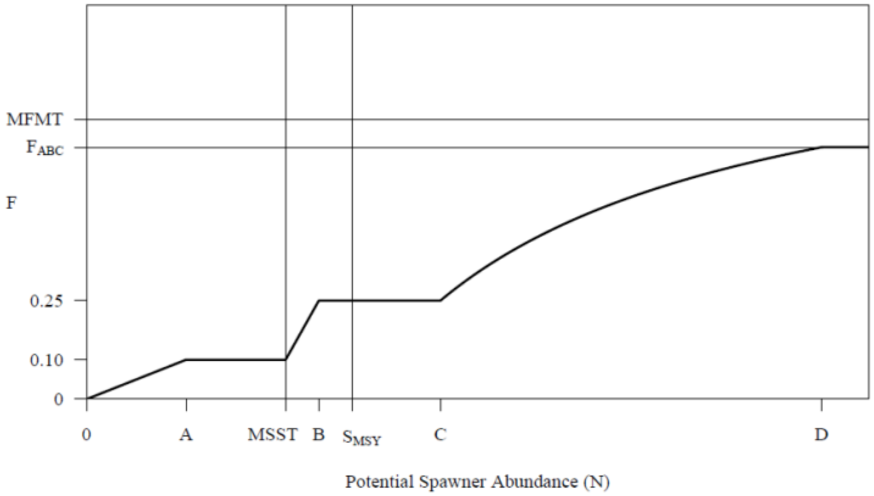

Figure 1. Control rule for UKTR fall Chinook Salmon and Sacramento River fall Chinook Salmon. Abundance is pre-fishery ocean abundance in spawner equivalent units, and F is the exploitation rate. Reference points in the control rule defined in the text.

Appendix D. Summary of Ford et al. (2020): Reviewing and Synthesizing the State of the Science Regarding Associations between Adult Run Timing and Specific Genotypes in Chinook Salmon and Steelhead: Report of a workshop held in Seattle, Washington, 27–28 February 2020

Given the multitude of recently completed and active genetic studies investigating specific genomic associations with run timing in salmonids, and their potential conservation and Endangered Species Act listing implications, NOAA Fisheries Northwest Fisheries Science Center convened a panel of fisheries geneticists in February 2020 to discuss the current state of the science and to identify areas of agreement, areas of uncertainty, conservation implications, and future research needs. The workshop was attended by federal, state, and academic geneticists and conservation planners. The proceedings became publicly available in June 2020 (Ford et al. 2020).

This appendix summarizes the main points presented in Ford et al. (2020). Many of these points refer to highly technical genetic and genomic research results and conclusions. These are reproduced and summarized here for reference in this California Endangered Species Act status review. Readers who require more information should refer to the original report referenced below.

Current State of Research

Summarizing the findings and recommendations presented in Ford et al. (2020), it is apparent that deconvoluting the genetic and genomic basis of run-timing is complex. It is generally accepted that run timing phenotypic variation is strongly correlated with genetic sequence variation in a relatively small (~200 Kb) region of the GREB1L/ROCK1 region of chromosome 28 in Chinook Salmon and steelhead. Run-timing variation is also affected to a lesser degree by effects of other genes and environmental factors.

There are two alleles in this region: an “early migrating” allele (E) and a “late migrating” allele (L). Fish with homozygous genotypes, EE and LL, exhibit early and late return timing, respectively. Heterozygotes (EL) generally exhibit an intermediate return timing, though, depending on the population, return can be skewed either early or late. The extent and importance of heterozygotes that possess both early and late arriving alleles is an active topic of debate. Results have been confounded by inconsistencies in sampling strategies between studies and effects due to habitat alteration over several decades.

It is unknown how genetic variation in the GREB1L/ROCK1 region actually causes variations in life history strategy – all of the studies to date have successfully established correlations, but not the actual biochemical pathways by which such variation functions in individual fish. Applying the current state of knowledge to conservation decisions is also a subject of debate. There were a few areas of agreement and many areas of disagreement – the issue is far from settled. A key conservation point where participants were in agreement is that conservation units should continue to be defined by patterns of genetic diversity across the genome (e.g.

microsatellite and SNP loci), not by variation in small genomic regions correlated with specific traits of interest, such as run-timing.

Areas of Agreement and Uncertainty

The following are verbatim points of agreement and uncertainty listed in Ford et al. (2020). The authors note that they did not attempt to come to consensus on these points. Rather, these were statements generally agreed upon by the meeting participants. Readers should refer to the original report for expanded discussions of each point below.

Is the GREB1L/ROCK1 region responsible for adult migration timing, and if so by what mechanism?

Areas of agreement:

1. A single region in the genome has a strong statistical association with adult run timing.
2. The migration phenotype measured across prior studies is not standardized, and efforts should be made to do so.
3. Marker development, validation, and standardization is extremely important.

Areas of uncertainty:

1. The causal variant(s) for adult run timing remain to be identified.

What is the distribution of genetic variation for adult migration timing in space and time? Do the genes associated with migration timing have the same effect in populations inhabiting different environments and with different genetic backgrounds?

Areas of agreement:

1. The GREB1L/ROCK1 association with run timing is best characterized in US West coastal populations for both Chinook salmon and steelhead, and to some degree in the Columbia River basin.

Areas of uncertainty:

1. Our current understanding of both the contemporary and historical distribution of genetic variation in GREB1L/ROCK1, in association with run timing, is confounded by issues with phenotyping, influence of hatchery populations, and anthropogenic activities influencing access to habitat across space and time.

What is the pattern of dominance among haplotypes in the GREB1L/ROCK1

genomic region? What phenotype do heterozygotes express, and what is their fitness compared to homozygotes?

Areas of agreement:

1. Heterozygotes are likely an important mechanism for the spread and maintenance of the early migration alleles over long time scales.

Areas of uncertainty:

1. It may be too simplistic to focus on dominance of migration timing alone since genetic variation at the GREB1L/ROCK1 region also could influence other traits that are more difficult to study.

In what circumstances is it reasonable to conclude that the current distribution of GREB1L genes accurately reflects historical (pre-European contact) patterns? When/where is that not a good assumption?

Areas of agreement:

1. Interaction between individuals with variable run timing has occurred historically, is expected, and likely varies depending on historical environmental conditions. However, anthropogenic impacts have also likely changed these interactions in many locations.

Areas of uncertainty:

1. It is unclear how much demographic isolation from fall run is required for spring Chinook salmon to persist.

How common are large-effect genes? Is it likely that strong associations will be found between specific alleles and many other phenotypic/life-history traits in salmon?

Areas of agreement:

1. Loci of large effect have been identified for other salmonid life-history traits.

Areas of uncertainty:

1. More data are needed from whole genome sequencing to know the extent to which complex traits are controlled by single genes of large effect, or many loci of smaller effect and how this various among populations.

Prince et al. (2017) concluded that the haplotypes associated with early migration timing evolved only once within each species. Is that the case, or are the genetic variants more evolutionarily labile?

Areas of agreement:

1. 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 that have been well characterized evolved long ago in each species' evolutionary history. It is also clear, based on available data, that the allelic variants for early migration have not arisen independently via new mutations from the genomic background of late migration individuals in each watershed.

<u>Needed Future Research</u>

The participants outlined the following areas for future research:

1. Better standardization and characterization of adult migration phenotypes in multiple populations and lineages, including when the 'decision' to migrate is made, how it relates to the timing of sexual maturity and the relationship(s) between the date of freshwater entry and subsequent upstream movements.
2. More thorough marker development and validation (see next section). Ideally, identification of the functional variant(s) in the GREB1L/ROCK1 region that cause alternative migration phenotypes.
3. Greater understanding of the physiological mechanisms leading to alternative migration phenotypes.
4. Tests for association of GREB1L/ROCK1 variation on phenotypes other than adult run timing, such as timing of sexual maturity or other life-history traits.
5. More thorough evaluations of the genetics of run timing variation, throughout the geographic range of Chinook salmon and steelhead, as well as studies in other salmon species in order to develop broad baseline data on the historical and current distribution of alleles at this locus. Current studies have been primarily focused on a limited number of West Coast and Columbia River populations. These investigations should include characterization of the full suite of genetic variants (and their effect sizes) contributing to run timing,
6. More thorough characterization of GRE1L/ROCK1 haplotype diversity and the phenotype and dominance pattern of each identified haplotype in multiple populations of both species, across their range.

7. Perform comparative analyses on systems with early-run and late-run populations that have been differentially impacted by human activities resulting in differing levels of interbreeding between life-history types, to determine how interbreeding might affect persistence of run type alleles.

Conservation Implications

Subsequent to the technical discussions, the participants discussed how the current state of knowledge should be applied to conservation decisions such as defining units for conservation, listing, and recovery. Their individual points are excerpted directly and presented here:

Commented [AC130]: Changes made by Christian Smith

Areas of agreement:

1. After discussion on whether conservation strategies might need to change based on the GREB1L/ROCK1 findings, the participants generally agreed that using patterns of genetic variation throughout the genome remains important for identifying conservation units, rather than identifying units based solely on small genomic regions associated with specific traits.
2. The workshop participants agreed that spring Chinook salmon and summer steelhead occupy a specialized ecological niche—upstream areas accessible primarily during spring flow events—that has made them particularly vulnerable to extirpation or decline due to habitat degradation.
3. The participants generally agreed that the evaluation of risk to early returning population groups (spring Chinook, summer steelhead) needs to consider what we now know about the genetic basis of adult return time.
4. The participants generally agreed that the finding that the early run trait has a simple genetic basis implies that it is at greater risk of loss than if it were highly polygenic because loss of the “early” allele(s) equates to the loss of the phenotype.

Commented [SC131]: This is the key – not monophyly.

Areas of uncertainty:

1. One area of uncertainty and potential disagreement at the workshop was the degree to which run timing diversity in spring Chinook salmon is partitioned among populations versus among individuals within a population.
2. The extent to which observed contemporary levels of interbreeding between individuals with early and late run timing would be typical under historical environmental conditions is unknown
3. Understanding the conservation implications of dominance patterns at the GREB1L/ROCK region is also important and is complicated because of tradeoffs between the probability of persistence of the early-run allele and the feasibility of starting new early-run populations.
4. The dominance-recessive relationships might influence the success of colonization events.
5. Regardless to what extent current levels of interbreeding are a consequence of human mediated habitat alterations, such interbreeding, and the common occurrence of heterozygotes at the GREB1L/ROCK1 region presents challenges for status monitoring, recovery planning, and other management actions.

Commented [SC132]: And makes designation of spring run as an esu non-viable.

6. Improved strategies are needed for monitoring run timing and associated genetic variation.
7. What conservation measures can be put into place now with existing knowledge? Conservation measures for spring run that were discussed included potentially shaping fisheries to focus disproportionately on fish with fall run timing, restoring access to spring-run habitat that has been blocked, considering restoring natural barriers that have been modified to increase fall-run access to historically spring-run habitats, and restoring more natural flow regimes (e.g., low summer flows that prevent mature migrating individuals from encroaching on premature habitat). Workshop participants agreed that the presence of heterozygotes does not in itself indicate a threat to the viability of spring-run as these heterozygotes contain alleles that may be important to spring-run restoration. Some workshop participants also noted, however, that in some cases the presence of high proportions of heterozygotes might represent a departure from the historical conditions and a warning sign that the spring-run phenotype is at risk.

<u>Issues Specifically Associated with Steelhead</u>

1. One major factor to consider regarding the conservation implications of the genetics of run timing diversity in steelhead is the existence of conspecific resident rainbow trout populations that may effectively act as reservoirs for the “early” GREB1L/ROCK1 alleles.
2. Another factor to consider for steelhead compared to Chinook is the generally greater amount of life-history diversity found in *O. mykiss*.

Report Citation

[18]Ford, M., K. Nichols, R. Waples, E. C. Anderson, M. Kardos, I. Koch, G. McKinney, M. R. Miller, J. Myers, K. Naish, S. Narum, K. G. O'Malley, D. Pearse, T. Seamons, A. Spidle, P. Swanson, T. Q. Thompson, K. Warheit, and S. Willis. 2020. Reviewing and Synthesizing the State of the Science Regarding Associations between Adult Run Timing and Specific Genotypes in Chinook Salmon and Steelhead: Report of a workshop held in Seattle, Washington, 27–28 February 2020. U.S. Department of Commerce, NOAA Processed Report NMFS-NWFSC-PR-2020-06.

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