Assessment of Scott River Salmon Performance Under Historical, Current, and Restoration Scenarios

August 9, 2021

Submitted to

Karuk Tribe

Prepared by

Larry Lestelle

Biostream environmental

17791 Fjord Drive NE Suite AA
Poulsbo, WA 98370
360-697-6702

Acknowledgements

The need for this assessment was recognized by staff of the Karuk Tribe. In particular, three individuals understood the importance of conducting a thorough assessment of the effects of the extensive alterations made by human activities over the course of time on the salmon populations of the Scott River; these individuals were Leaf Hillman, Craig Tucker, and Toz Soto. Further, they saw the need to assess the prognosis for the fish populations going forward into the future without some form of effective intervention. They asked: What would it take to prevent extirpation? Their recognition of the critical status of the existing populations is given special acknowledgement here.

I also acknowledge the useful observations and related insights provided to me about the watershed and the fish populations, as well as data and other information, by the following:

Toz Soto, Karuk Tribe
Craig Tucker, Suits and Signs Consulting, LLC (formerly with Karuk Tribe)
Susan Fricke, Karuk Tribe
Crystal Robinson, Quartz Valley Indian Reservation
Tim Abbe, Natural Systems Design, Inc.
Bill Chesney, California Department of Fish and Wildlife (retired)
Rocco Fiori, Fiori Geological Science
Deborah Hathaway, S.S. Papadopulos & Associates

I am grateful for the assistance of key staff of ICF International, the owner of the EDT model, in assisting in performing the modeling used in the assessment; these individuals were Greg Blair, Laura McMullen, and Karl Dickman.

Special thanks are given for the peer review of the report arranged by Nicholas Hetrick, Arcata Fish & Wildlife Office (U.S. Fish and Wildlife Service) from Ken Collis (Senior Fish and Wildlife Scientist with Real Time Research, Inc.) and Kevin Malone (senior consulting biologist with extensive EDT modeling experience). Their suggestions and comments were most helpful and appreciated. Their comments and my responses are summarized in Appendix F of this document.

Special thanks and acknowledgement is given to Craig Tucker and Leaf Hillman of the Karuk Tribe in arranging for funding—and especially for their patience and understanding while the report was being completed given its delay in delivery.

Table of Contents

Appendix E - Historical and Current Baseline Flow and Wetted Width in August

Appendix F - Reviewers' Comments and Responses

List of Figures

List of Tables

Executive Summary

Introduction

Salmon populations in the Scott River watershed in Northern California have suffered sharp losses over the past century due to many contributing factors. The coho salmon population, now a small remnant of its past abundance and part of broader conservation units, is listed as threatened under both the California Endangered Species Act (CESA) (CDFG 2004) and the Federal Endangered Species Act (ESA) (62 FR 24588, May 6, 1997). Spring Chinook salmon, once abundant in the watershed, were extirpated in the last century. The fall Chinook salmon population, the only remaining salmon population that demonstrates some degree of stability, has also experienced substantial loss.

This report presents an assessment of the effects of habitat changes on the performance of salmon species in the Scott River watershed. The assessment is aimed at answering two questions: What is broken in the watershed with respect to salmon performance, and what needs to be fixed? Answering these two questions is fundamental to developing an effective restoration and salmon recovery action plan for the subbasin— if indeed such a plan can be developed and implemented. Based on the analysis of these questions, I provide guidance for taking actions in the subbasin to help restore critical habitats and support recovery of the salmon populations.

The modeling analysis did not consider potential effects on the Scott River populations of dam removal actions being planned in the mainstem Klamath River.

The assessment is presented in three parts: (1) an analysis of historical and current baseline habitat conditions and associated salmon performance; (2) a diagnosis of the effects of past habitat alterations on salmon performance, and (3) an analysis of a set of generalized habitat restoration scenarios to address major limiting factors and provide guidance for prioritizing actions.

Approach

The approach used for the assessment is built on the Viable Salmonid Population (VSP) framework, the theoretical basis developed by NOAA Fisheries for describing salmon population performance used in recovery and restoration planning. The EDT Method, which is rooted in this framework, served as the analytical suite of tools for analyzing population performance. These conceptual and analytical methods provided the basis for developing and analyzing generalized restoration scenarios to give guidance for future restoration planning. The VSP concept is defined by four characteristics that describe performance of a salmon population: abundance, intrinsic productivity, biological diversity, and spatial structure.

EDT is a suite of tools developed to provide natural resource managers with a process for organizing information and developing a scientifically credible plan for moving forward with salmonid restoration and protection. The tools include an analytical model to facilitate analysis and evaluation of potential actions for restoration and protection planning. The model explicitly links actions to projected outcomes and provides a framework for decision making to help address scientific uncertainty and environmental variability.

The EDT model is a salmonid life-cycle habitat model that assesses the potential of habitat to support species and populations using VSP metrics. The model is designed to assess environmental constraints on a salmonid population. It predicts the ways in which salmonid populations respond to changes in the aquatic environment, allowing managers and planners to explore alternative habitat restoration strategies and potential future land use decisions. The model is also being used to assess the effects of future climate change conditions on salmonid populations for restoration planning.

The EDT model has been widely used throughout the Pacific Northwest and parts of California to assess salmonid population performance in relation to various environmental factors. It has been most widely used for salmon and steelhead recovery planning. The model was used previously in the Klamath Basin as part of PacifiCorp FERC relicensing and for conducting a limiting factors analysis in the Shasta River.

Several generalized restoration scenarios were developed for analysis in the Scott River subbasin using the EDT model. The purpose of this part of the assessment was to help understand and evaluate the kinds, magnitude, locations, and intensities of actions that would be required to produce substantial changes in performance of the three Scott River salmon populations. The scenarios were developed as "what ifs."

The scenarios were developed around some specific themes of restoration actions that might be considered for the subbasin. Each theme for restoration was meant to represent a category of action types that could be implemented. The categories consisted of restoration of surface flow that could result from a reduction of groundwater pumping, riparian restoration, floodplain channels restoration, and a combination of those three categories.

Historical Overview

An overview of the known or inferred characteristics of the Scott River subbasin and the three salmon populations of interest to this assessment is provided. The review covers the major environmental alterations that were made to the subbasin over the past roughly 200 years that have resulted in its current condition. Similarly, the relevant characteristics are reviewed of the salmon populations as we can reasonably assume existed over this period of time. This overview gives context and background information for performing the assessment and for helping to judge its accuracy and potential application.

Historical and Current Baselines

Methods

The EDT model was configured for analyzing the historical and current salmon populations produced in the Scott River subbasin. The standard procedures used in EDT modeling were applied. Species modeled were coho, fall Chinook, and spring Chinook salmon. Habitat potential for historical and current production scenarios were evaluated for the three salmon populations.

Results

For coho salmon, the modeling results depict a massive decline (approximately 97%) in equilibrium abundance of adult salmon returning to the Scott River subbasin over roughly the past 200 years in the absence of all fishing. This loss is reflected in each of the VSP metrics evaluated by the model and is shown to have occurred to each of the major population components. The results are given for the aggregate combined spawning population (entire subbasin) and for four spawning aggregations delineated by major areas of the subbasin: (1) Forks – South and East Fork combined; (2) Upper valley – all stream reaches downstream of the forks and upstream of Etna Creek (including Etna Creek); (3) Lower valley – all stream reaches downstream of Etna Creek and upstream of the USGS flow gauging station just downstream of the valley; and (4) Canyon – all stream reaches downstream of the USGS gauging station and upstream of the confluence with the Klamath River.

For fall Chinook salmon, the modeling results demonstrate a large loss in equilibrium abundance (approximately 70%) between the historical and current baselines in the absence of all fishing. The loss is reflected in each of the VSP metrics evaluated by the model and has occurred in each of the major population components. The population was delineated by three spawning aggregations: (1) Upper valley – all stream reaches downstream of the forks and upstream of Etna Creek (including Etna Creek); (2) Lower valley – all stream reaches downstream of Etna Creek and upstream of the USGS flow gauging station just downstream of the valley; and (3) Canyon – all stream reaches downstream of the USGS gauging station and upstream of the confluence with the Klamath River.

For spring Chinook salmon, the modeling results similarly show an enormous loss in equilibrium abundance (approximately 90%) between the historical and current baselines in the absence of all fishing. The population is believed to have been extirpated in the early 1970s. The loss is reflected in each of the VSP metrics evaluated by the model and shows similar magnitudes of decline in each of the major population components that were modeled. Although the VSP metrics at first glance might suggest that spring Chinook could still inhabit the river system, the results on closer inspection do not support that. The population was delineated by three spawning aggregations: (1) Upper valley – all stream reaches downstream of the forks and upstream of Etna Creek (including Etna Creek); (2) South Fork – all stream reaches in the South Fork; and (3) East Fork – all stream reaches in the East Fork.

Diagnosis and Prioritization

Methods

The EDT model was designed to produce what is commonly referred to as a stream reach analysis, which is used in diagnosing the relative importance of individual stream reaches (or groups of reaches) and each habitat survival factor associated with those reaches in affecting population performance. The detailed reach structure within the model provides the means to analyze stream reach priorities for both protection and restoration. This is done in two parts – one part that analyzes the effect of degrading the reach to a standardized fully degraded reach environment (called the protection analysis) and the other part that analyzes the effect of fully restoring the reach to its historical condition (called the restoration analysis).

Results

Detailed results are provided for each species that rank geographic areas (groups of stream reaches) by restoration and protection priority. This is followed by consumer report style graphics that identify the relative contribution of different habitat survival factors to the decline of each species' performance associated within each geographic area. To do this, the environmental attributes are rolled up into what EDT refers to as habitat survival factors. These factors are expressed in terms that biologists often use in limiting factors analysis.

Restoration Scenario Analysis

Methods

Four distinct restoration scenarios for modeling were developed to compare population performance for the three salmon populations under a wide range of restoration approaches applicable to the Scott River subbasin. These scenarios were focused entirely on actions that might be applied within that subbasin. No consideration was given to attempting to model the effects of dam removal in the mainstem Klamath River as part of the restoration effort.

These scenarios are not meant to be realistic proposals for restoration—they are hypothetical "what ifs." They were developed to help inform about the kinds, magnitude, locations, and intensities of restoration actions that would be needed to bring about a substantial improvement in the performance of the three populations. A meaningful and effective restoration program would need to include elements of these hypothetical scenarios as well as other elements. The four scenarios are referred to as

1. Prepumping Flow Restoration Scenario
2. Riparian Restoration Scenario
3. Floodplain Channels Restoration Scenario
4. Combination Restoration Scenario

To parameterize model inputs for the restoration scenarios, the values of the EDT environmental attributes were adjusted from the current baseline for all relevant stream reaches to correspond to the scenario descriptions. Procedures normally applied in these kinds of EDT assessments were used.

Results

Highlights of the results of the four scenarios are given here for coho to illustrate how the results are presented in the report.

Highlights of the Prepumping Flow Restoration scenario are summarized below:

- The geographic scope of restoration covered was limited to the area of major groundwater pumping in the subbasin. Restoration occurred to increase surface flow in affected reaches to what would result from ending groundwater pumping.

- The prepumping wetted channel width at the downstream end of the valley for September was estimated to increase by 50% compared to the current baseline width (Table 6-2), from an average of 40 ft to 60 ft.
- Coho population performance was estimated to produce a modest increase (16%) in Neq spawner abundance (to about 480 spawners) and a very small increase (2.1%) in population productivity at the subbasin scale. The increase in Neq for the upper valley population component was somewhat larger (23.5%).

Highlights of the Riparian Restoration scenario are summarized below:

- The geographic scope of restoration covered was the riparian zone of the entire river system as modeled. Restoration occurred to restore the historical vegetation structure of the entire riparian zone along the mainstem Scott River and all of its tributaries. No changes were assumed to occur for channel structure, either within the riparian zone or within the in-stream channels. No changes to in-stream flow amounts were assumed to occur.
- The Neq abundance of the aggregate coho population was estimated to more than triple its size compared to the current baseline (235% increase)—increasing to about 1,400 spawners. Productivity increased by approximately 24%. The life history diversity metric increased by nearly 1000%.

Highlights of the Floodplain Channels Restoration scenario are summarized below:

- The geographic scope of restoration covered was the areas of the floodplains of the entire river system as modeled. Restoration occurred to restore the historical floodplains channel structure of the entire river system along the mainstem Scott River and all of its tributaries. No changes were assumed to occur to the riparian vegetation, in-stream flow amounts, or channel structure of the main channels of the mainstem Scott River or its tributaries.
- The Neq abundance of the aggregate coho population was estimated to more than quadruple its size compared to the current baseline (356% increase)—increasing to about 1,900 spawners. Productivity increased by approximately 18%. The life history diversity metric increased by about 900%.

Highlights of the Combination Restoration scenario are summarized below:

- The geographic scope of restoration covered was limited to the area of major groundwater pumping in the subbasin. Restoration actions consisted of a combination of actions contained in the other three restoration scenarios—groundwater restoration, riparian restoration, and floodplain channel restoration. The intensity of restoration treatment was reduced by half of the rates applied in the other scenarios. Main stream in-channel structure was also assumed to be partially restored as a result of the riparian and floodplain focused actions.
- The increase in population performance was substantially greater for this scenario than for any of the other scenarios.

- The Neq abundance of the aggregate coho salmon population was increased by approximately 7x of that in the current baseline (~600%)—increasing to about 2,900 spawners.
- Productivity was increased by approximately 74%, much more than in any other scenario—increasing to about 4.6 adult returns per spawner.
- The life history diversity metric increased by about 900%--increasing to about 48%.

These scenario results together indicate that an effective restoration plan would need to address multiple limiting factors and be carried out at a large enough scale to be truly meaningful. The Combination Restoration scenario presented here would likely be capable of producing sufficient resiliency to reduce the risk of extirpation to an appropriate level, although the subpopulation produced in the South and East Forks would remain threatened. The Combination scenario as outlined here does not direct any restoration to habitat within the forks.

Conclusions

The diagnostic conclusions of this assessment are not surprising. Many of the findings presented herein are consistent with findings and conclusions of other assessments and research. Of the two remaining Scott River salmon populations, the coho population is clearly in trouble—trending downward and subject to wide variation with a spatially fragmented distribution. The other remaining population, fall Chinook, is also arguably in trouble as reflected in its declining percentage of the overall Klamath River wild fall Chinook population. These patterns suggest that both populations have an increasing risk of extirpation, though risk levels differ between the two populations. The modeling results are consistent with and support these observations.

Today, the abundance, productivity, and life history diversity of the salmon populations are barely a shadow of their former characteristics. Spring Chinook salmon were extirpated in the early 1970s. Coho salmon have declined precipitously, and the risk of extirpation is high and worsening. Fall Chinook salmon have been substantially reduced, increasingly having difficulty of being able to ascend into the valley and its tributaries to spawn; population stability appears precarious and subject to wide variation.

There are multiple reasons for the decline of the Scott River salmon populations. These include a multitude of habitat-related factors, beginning in the mid-1800s and intensifying since then. Effects of those factors extend throughout the entire Scott River system. These factors encompass practically every aspect of habitat used by salmon in the river system: streamflow, riparian interface, sediment load, habitat type composition, water temperature, channel structure, available food, and others.

As the effect of these factors increased over the past century, harvesting of the salmon runs also increased, both in the ocean and in the Klamath River. Added to these factors were changes that occurred within the mainstem Klamath River due to construction and operations of upriver dams along with other upstream flow management activities managed by the U.S. Bureau of Reclamation. A major hatchery was constructed and operated just downstream of Iron Gate Dam, which has annually released large numbers of fall Chinook and coho salmon. These operations within the mainstem Klamath River are believed to have substantially worsened the effect of fish diseases within the mainstem river, particularly associated with *C. Shasta*.

The combination of all of these factors—their cumulative effect—is ultimately the reason for the decline of the three salmon populations. More recently, climate change-related factors have contributed—exacerbating effects of the other factors. Northern California remains in a long-term drought, which has been particularly severe in recent years.

Within the Scott River subbasin, watershed and biological processes critical to salmon are broken. These include processes that affect hydrologic patterns, sediment transport, water temperature patterns, riparian structure, channel structure and dynamics, connectivity of habitats, cycling of marine-derived nutrients, beaver influences, and others. Among these, the key watershed process that is broken is the flow regime.

The three major causes of the natural flow regime being altered have been (1) land conversion and associated changes in floodplain water storage and channel structure through the Scott Valley and into large parts of the forks, (2) the almost ubiquitous surface water diversions throughout the river system upstream of the canyon, and (3) major groundwater pumping occurring in roughly the lower half of the valley. Periodic droughts resulting from climate cycles and long-term climate change patterns have acted to exacerbate the effects of the human-caused alterations.

The weight of evidence indicates that the prognosis for sustaining the Scott River salmon populations is bleak without major interventions. Salmon habitat conditions within the subbasin are on the whole in extremely poor condition, even though there are some areas of the subbasin in relatively good condition—and a few that could be classified as in very good condition. However, habitats capable of sustaining salmon production are generally disconnected (i.e., not contiguous) from one another, such that the spatial distribution of salmon use in the subbasin is fragmented. These conditions tend to create islands of production scattered in the subbasin—separated both spatially and temporally, which over time greatly increases the risk of extirpation.

The root problem is that the resiliency of watershed processes that create and maintain habitats needed to perpetuate the salmon runs has been lost. Similarly, the resiliency of the salmon populations to sustain themselves in the face of environmental variability and climate change has been substantially lost. Intrinsic productivities are low and spatial structure (distribution) has been much reduced and fragmented.

A comprehensive, aggressive restoration program is urgently needed to reverse the downward trajectories of performance of the two remaining salmon populations in the Scott River subbasin. Without such an effort, the coho population will continue to dwindle, before it finally blinks out. I expect that fall Chinook, while currently more stable than coho, will also continue a downward slide.

The restoration efforts that have occurred over the past several decades have helped both populations – diversion screens, fencing, riparian plantings, water leases – but these efforts, while commendable, can generally be described as insufficient to reverse the declines in performance. A larger, more extensive, and coordinated program is needed.

Such a program would necessitate that both the relevant federal and state entities act to fulfill their public trust responsibilities for these resources. Coho salmon, as both a federal and state ESA-listed species, will assuredly be extirpated in the relatively near future without aggressive intervention to restore resiliency to the population. And arguably, the fall Chinook salmon population should also engender both federal and state intervention actions under public trust responsibilities.

Is it possible to envision a Scott River subbasin restored to normative ecosystem functions, supporting productive, diverse salmon populations—even in the face of climate change, as well as providing for sustainable social, cultural, and economic values within the subbasin? This question is posed for agencies, managers, and stakeholders to consider.

Assessment of Scott River Salmon Performance Under Historical, Current, and Restoration Scenarios

1. Introduction

Salmon populations in the Scott River watershed in Northern California have suffered large and significant losses over the past century due to many contributing factors. The coho salmon population, now a small remnant of its past abundance and part of broader conservation units, is listed as threatened under both the California Endangered Species Act (CESA) (CDFG 2004) and the Federal Endangered Species Act (ESA) (62 FR 24588, May 6, 1997). Spring Chinook salmon, once abundant in the watershed, were extirpated in the last century (Moyle 2002). The fall Chinook salmon population, the only remaining salmon population that demonstrates some degree of stability, has also experienced substantial loss (Moyle et al. 2008).

This report presents an assessment of the effects of habitat changes on the performance[1] of salmon species in the Scott River watershed. The assessment is aimed at answering two questions: What is broken in the watershed with respect to salmon performance, and what needs to be fixed? Answering these two questions is fundamental to developing an effective restoration and salmon recovery action plan for the subbasin— if indeed such a plan can be developed and implemented. Based on the analysis of these questions, I provide guidance for taking actions in the subbasin to help restore critical habitats and support recovery of the salmon populations.

This assessment does not address steelhead performance. Considerable uncertainty exists about steelhead life history and abundance in the Klamath River basin (Barnhart 1994; Moyle et al. 2008) – and specifically for the Scott River subbasin. The modeling methods applied in this report would have been particularly challenging given the complex life histories that are known to exist within the Klamath basin.

The Scott River watershed (Figure 1-1) is a major subbasin of the Klamath River basin. Historically, this subbasin produced large runs of coho, fall Chinook, and spring Chinook salmon, as well as steelhead trout, and it was a major producer of these species within the Klamath River system (NRC 2004; Moyle et al. 2008).

The factors responsible for the declines of salmon populations in the Scott River can generally be grouped into two categories—habitat and harvest. Of these, there is little question that habitat alterations have by far been most responsible in recent decades, although high harvest rates undoubtedly had significant adverse impacts during a large part of the 20th century (Snyder 1931; CDFG 2002; NRC 2004). Harvest management is regulated by federal, state, and tribal agencies and is given

---

[1] / NOAA Fisheries defines salmon population performance in terms of key parameters, or characteristics, that describe how the population responds from interactions with its habitat (McElhany et al. 2000); see Section _of this report for details.

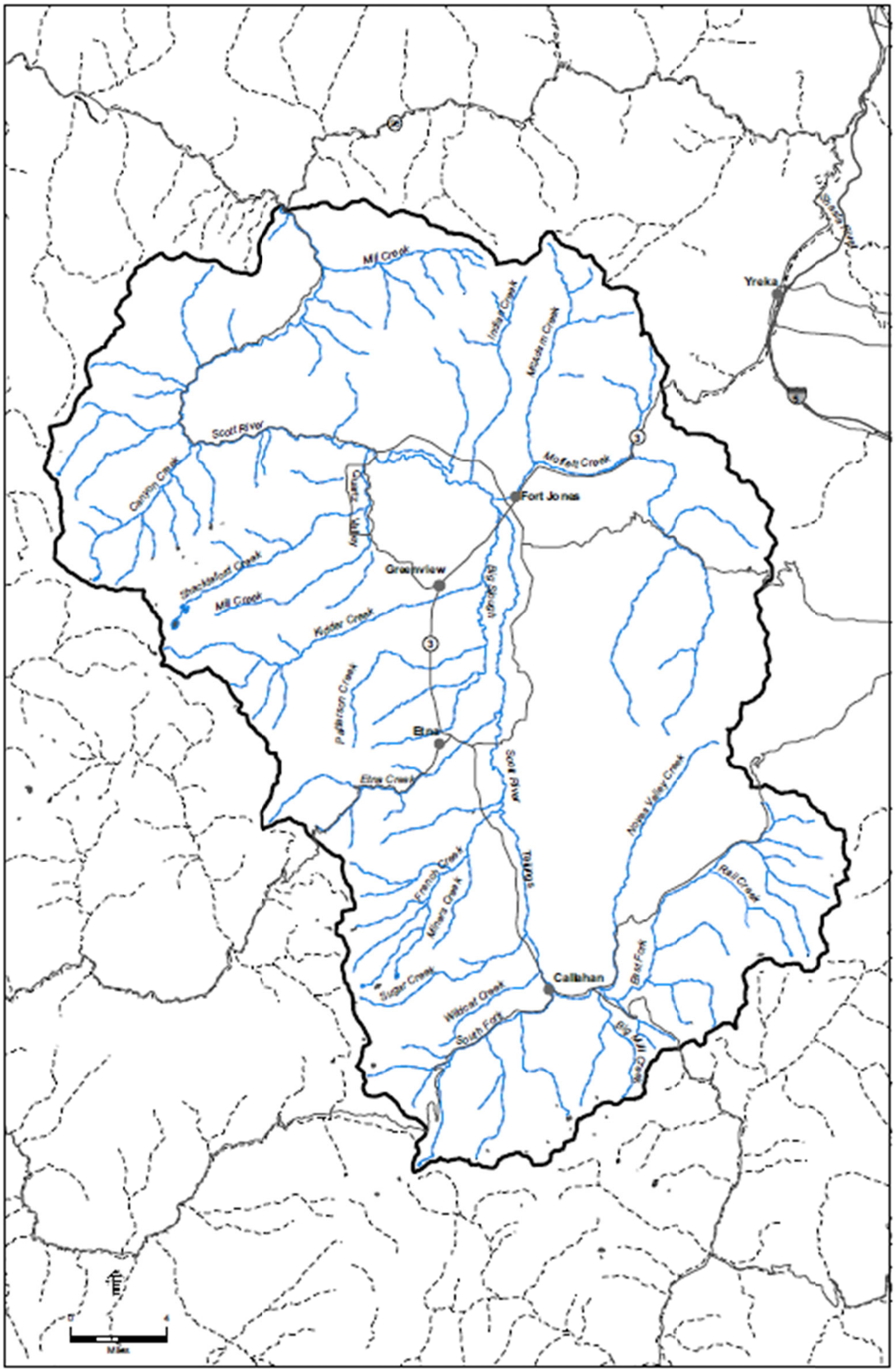

Figure 1-1. The Scott River subbasin. Map taken from ESA (200).

much attention to keep harvest rates within limits, which are much reduced from historical rates (CDFG 2002).[2] In contrast, watershed characteristics and processes have been greatly altered through land and water uses in all areas of the watershed. These alterations have resulted in significant changes to the physical and thermal attributes of habitats used by aquatic and semi-aquatic species in the watershed—most dramatically for habitats relied upon by salmon species.

This assessment is presented in three parts: (1) an analysis of historical and current baseline habitat conditions and associated salmon performance; (2) a diagnosis of the effects of past habitat alterations on salmon performance, and (3) an analysis of a set of generalized habitat restoration scenarios to address major limiting factors and provide guidance for prioritizing actions.

Part one of the assessment describes two baseline conditions that are important to the diagnosis, a historical baseline and a contemporary baseline. The historical baseline is characterized by a set of environmental conditions that can reasonably be described for the period prior to watershed development with the arrival of Euro-American settlement. The current baseline represents an average set of conditions as they generally exist today. Average salmon population performance for each species and set of baseline conditions is then projected using modeling tools.

Part two of the assessment analyzes how current salmon performance levels have been affected by changes in habitat since watershed alterations began in the 1800s and continuing to the present. This part diagnoses the extent of the declines in salmon performance and the relative contributions of different habitat factors that led to the declines. Some of the major habitat factors that have been identified in past assessments include reductions in streamflow quantity due to irrigation withdrawals, loss of riparian shading and increased water temperatures, changes in stream morphology due to mining and channel straightening, and disconnection of stream channels from their floodplains (Sommarstrom et al. 1990; NRC 2004; NMFS 2014). The analysis presented here provides information needed to prioritize restoration actions that might be considered—i.e., what should be targeted for restoration and where should it be done.

Part three of the assessment considers the results of the diagnosis and assesses benefits to salmon performance of a range of potential habitat restoration scenarios within the watershed. The scenarios are presented as “what ifs.” They enable projections to be made of the levels of response in salmon performance that might reasonably be expected if such scenarios were to be implemented. Whether or how such restoration scenarios could actually be implemented is not considered, nor is it particularly relevant to the presentation. The scenarios are intended to inform about the scale and intensity of restoration efforts that would be required to produce the kinds of performance responses projected. In this sense, the scenario analysis serves as another aspect of the diagnosis.

---

[2] / Despite efforts to control harvest rates within specific limits based on run size forecasts and stock status, harvest can sometimes exceed these limits in any given year. In 2018, NMFS found that Klamath River fall Chinook were overfished in 2015-2017 as the term “overfished” is defined in the Pacific Fishery Management Council’s (PFMC) Pacific Coast Salmon Fishery Management Plan. Consequently, PFMC has developed a rebuilding plan for the population by adjusting current fisheries and considering certain habitat-related actions (NMFS 2020).

The habitat restoration scenarios are focused to a large extent on the area of the subbasin where groundwater pumping primarily expanded in the 1970s. This geographic area, which covers a large part of the Scott Valley, has undergone major environmental alterations for more than a century—but groundwater pumping developed relatively recently compared to the much longer history of alterations in the subbasin. Its relatively recent effect on the flow regime of the Scott River is clearly evident. A report by S.S. Papadopulos & Associates (2012) that analyzed the effects of groundwater pumping on surface flows gave impetus for the assessment contained herein.

The results of the three parts of the assessment combined provide guidance for developing a meaningful salmon restoration plan for the watershed.

This assessment has three major objectives:

1. Identify using modeling the extent of declines in performance of the coho, fall Chinook, and spring Chinook populations in the Scott River subbasin that have occurred as a result of alterations to habitat characteristics within the watershed;
2. Diagnose the major limiting factors affecting salmon populations within the subbasin, both with respect to where and what those factors are, and prioritize restoration and protection measures that would improve population performance; and
3. Provide projections of the extent of improved population performance that could reasonably be expected under a set of habitat management scenarios for the subbasin.

The assessment is based on application of the Ecosystem Diagnosis and Treatment (EDT) Method to each of the three salmon populations of interest. This method, which includes the EDT model, is a widely used tool in the Pacific Northwest and California for diagnosing habitat factors affecting salmon population performance and for salmon recovery planning (Lestelle et al. 1996; Blair et al. 2009; Thompson et al. 2009; McConnaha et al. 2019; Doyle et al., *In press*). The method provides a systematic way of diagnosing habitat conditions that have contributed to the current state of populations, and it enables an assessment of priorities for developing restoration and protection plans. It also provides an analytical procedure for assessing the potential benefits to salmon populations of actions that might be taken to address habitat related issues impeding recovery.

The report is organized into the following major sections:

1. Introduction;
2. Approach;
3. Historical Overview;
4. Historical and Current Baselines;
5. Diagnosis and Prioritization;
6. Restoration Scenario Analysis; and
7. Conclusions.

2. Approach

The approach used for the assessment is built on the Viable Salmonid Population (VSP) framework, the theoretical basis developed by NOAA Fisheries for describing salmon population performance used in recovery and restoration planning (McElhany et al. 2000). The EDT Method, which is rooted in this framework, served as the analytical suite of tools for analyzing population performance. These conceptual and analytical methods provided the basis for developing and analyzing generalized restoration scenarios to give guidance for future restoration planning.

2.1. Viable Salmonid Populations

The VSP concept is a theoretical framework developed by NOAA Fisheries to guide assessment and recovery under the ESA (McElhany et al. 2000). The concept was developed to define the essential characteristics of a viable salmon population, i.e., one that has less than a 5% probability of extinction over the next 100 years. The concept provides the theoretical basis for describing different aspects of salmon performance that together define long-term viability.

In addition to defining viability, the concept provides a basis for evaluating how salmon population performance might be affected by restoration actions or future habitat degradation, including the effects of climate change. The goal of salmon recovery is not simply to ensure persistence of species within a river basin—it also aims to achieve levels of salmon performance that can sustainably deliver ecosystem services, which can include a range of societal objectives (Lestelle et al. 2018). Analytical models, such as the EDT model applied in this assessment, are used to evaluate how recovery actions can improve population performance.

The VSP concept is defined by four characteristics that describe performance of a salmon population: abundance, intrinsic productivity[3], biological diversity, and spatial structure. These four characteristics are often referred to as the VSP parameters or metrics; each is defined below.

- <u>Abundance</u> is the size of a population, a subpopulation, or other relevant demographic unit. Small populations are at greater risk of extinction than large populations and provide less ecosystem services than larger ones. Both habitat quantity and quality in each life stage of the species contribute to observed abundance.
- <u>Productivity</u>, and specifically intrinsic productivity as applied here, determines how rapidly a population can rebound when abundance is driven to low levels due to some form of disturbance (such as a flood or inadvertent overharvest). Populations with low intrinsic

[3] / The meaning of the term “productivity” can differ in the salmon restoration literature. Often the term is used to mean the population’s growth rate from one generation to the next; in this sense it is the number of adult progeny produced per parent spawner (or recruits per spawner) measured for each generation. The term is also used to refer to what is called intrinsic productivity, which McElhany et al. (2000) defines as the maximum population growth rate when free of density-dependent limitations. Population growth rate for salmon populations, expressed simply as recruits per spawner, is highly density dependent for populations that fluctuate widely. In this report, the term productivity will be used in the sense of intrinsic productivity, as it is usually applied in population dynamics literature (e.g., Hilborn and Walters 1992).

productivity are at higher risk of extinction due to future degradation resulting from watershed development or climate change.

- Diversity in genetic and/or life history characteristics provides resilience for a population to cope with short-term environmental disturbances or long-term environmental changes. In this sense, these characteristics are similar to diversification in an investment portfolio—long term success depends on diversity.
- Spatial structure (or spatial distribution) describes foremost how the spawning population is distributed but also considers the dispersal and distribution of progeny. Spatial structure is a geographic analogue to biological diversity (Kaje 2008; Lestelle et al. 2018) because it operates to diversify the spatial distribution of the population, protecting it against differential short- and long-term changes across the environment.

It is important to understand the relationship between abundance and productivity, which is best illustrated within a conventional stock-recruitment (S-R) modeling structure, also referred to as a spawner-production (S-P) curve. One typical form of the S-P model is called the Beverton-Holt (B-H) (Beverton and Holt 1957), which describes the underlying relationship between spawners and their progeny in a manner whereby the number of progeny produced approaches an asymptotic limit or capacity (Figure 2-1). This form of the S-P relationship is applied in the EDT model.

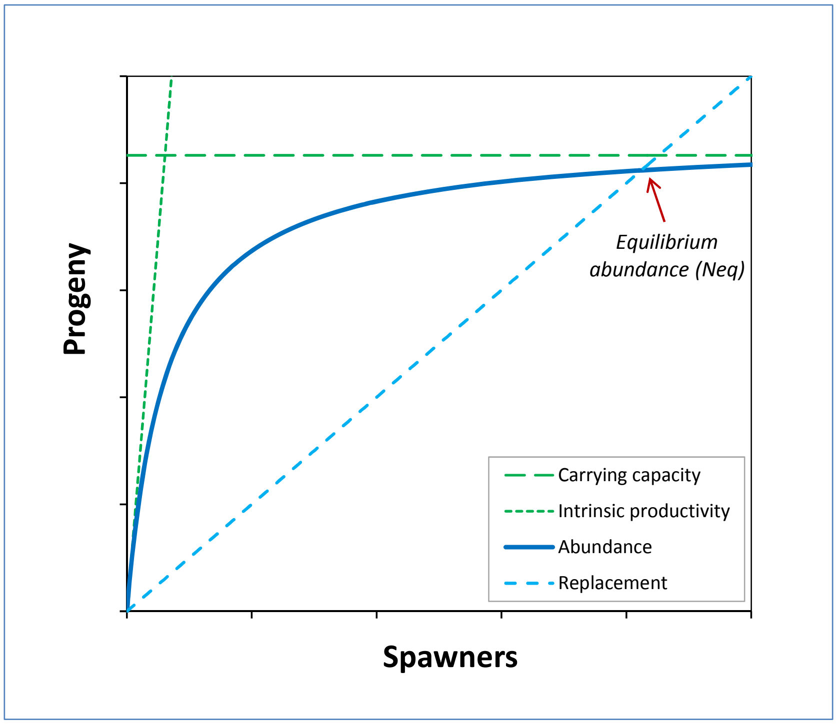

Figure 2-1. Spawner-production (S-P) relationship.

Two parameters determine the shape of the B-H production curve, shown in Figure 2-1. The productivity parameter is the slope of the relationship at low spawner density, representing the intrinsic production of the population that would occur in the absence of any competition for resources. This is an extremely important parameter that reflects the capability of the population to withstand stresses like environmental variability or harvest. Intrinsic productivity is determined by habitat quality, i.e., those aspects of habitat that the population does not compete for; for example, water temperature, fine sediment within spawning gravels, and the distribution and occurrence of refugia habitats (affecting the ability of individuals to find these habitats). These factors operate without being affected by population density.

The capacity parameter defines the asymptotic limit for the size of the population as a result of limited resources like food and living space. The effects of habitat capacity on population performance are determined by factors that operate through density dependence. The capacity parameter is determined by the quantity of habitat in combination with the quality of those habitats. Living space and food, and their quality, are the determinants of capacity.

The blue dashed diagonal line in Figure 2-1 is the replacement line, showing where the resulting production from any level of spawners would just equal the number of parent spawners that produced it. The difference between the solid blue abundance line and the diagonal replacement line is called surplus over replacement, and it represents the size of theoretically sustainable harvest. The point where the production curve crosses the replacement line reflects where the population would tend to equilibrate under steady-state conditions in the absence of all fishing—it is usually referred to as equilibrium abundance (or Neq) in models like EDT.

Surplus over replacement has important meaning for conservation and restoration planning. The greater the surplus over replacement, the more capability the population has to respond to short-term disturbances to the system, such as floods, droughts, heat waves, and downturns in marine survival. The amount of surplus over replacement is affected by both productivity and capacity, but productivity determines how “flat” the curve is, that is, how close the curve gets to the replacement line on its ascending limb. Figure 2-2 shows a B-H curve with a much reduced productivity value compared to Figure 2-1, which flattens the curve. The flatter the curve is to the replacement line, the more likely the population will be adversely affected by floods, climate change trends, overharvest, and variability in marine survival. In other words, the amount of surplus over replacement, and how flat the curve is relative to the replacement line, is an indicator of resilience in the population to stressors.

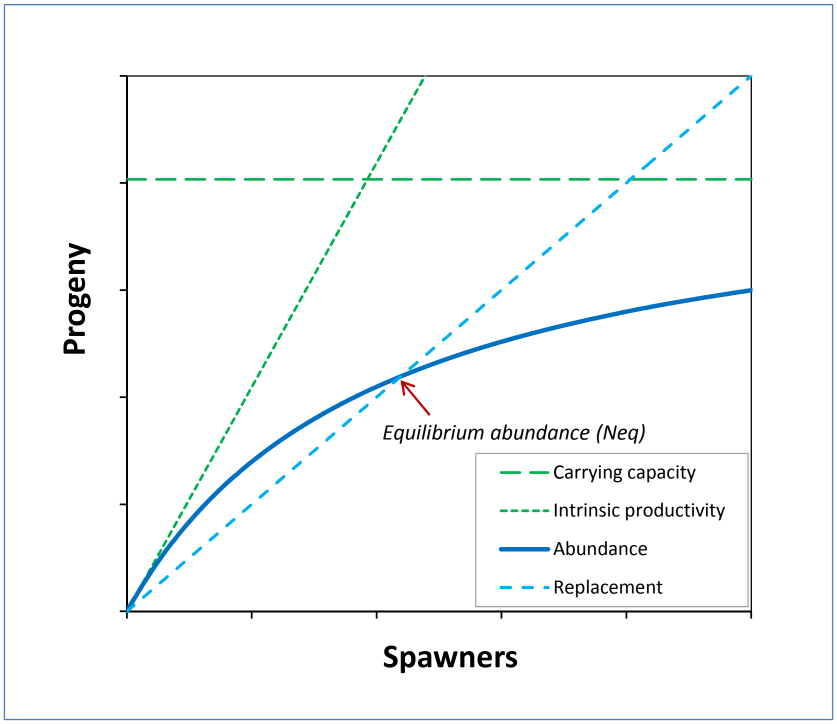

Figure 2-2. Spawner-production relationship with reduced productivity compared to the relationship in Figure 2-1.

The other two terms used in the VSP framework, “spatial structure” and “diversity”, are very closely related and address how a population adapts and distributes among the many diverse habitats across a large geographic area as the Scott River subbasin. Over long periods of time, diverse spatial structure leads to biological diversity through evolutionary processes. Spatial structure, which is a measurable characteristic, can therefore serve as an indicator of biological diversity, which changes slowly over time (Lestelle et al. 2018). Both spatial structure and biological diversity are critically important in affording resilience to salmon populations, better enabling them to cope with and adapt to a changing and variable environment.

Another important aspect of salmon population performance that affects long-term viability and extinction risk is the amount of variation in production that occurs as a result of variability in natural processes among years (McElhany et al. 2000; ICTRT 2007). Relatively wide variation in production is often seen in spawner-recruit data sets, as shown in the hypothetical data set in Figure 2-3 (Hilborn and Walters 1992). The amount of interannual variation appears to be an important factor affecting Scott River salmon populations and is discussed later in this report. The importance of this factor is introduced to the reader here within the context of the VSP framework and S-P relationship. Whereas the underlying S-P relationship shown in Figure 2-3 is expressed by a deterministic function, the actual number of recruits produced at any level of spawners reflects many interacting stochastic (i.e., random) environmental and biological effects. The result is that empirical data can have a large amount of scatter around any underlying S-P relationship.

It is important to note from Figure 2-3 the pattern of scatter of observed data points. The common distribution of data points is called a lognormal distribution—it shows occasional very large recruitment, having a long tail toward the upward end. The amount of variation at a given level of spawners will be proportional to the average recruitment at that spawner level, so we expect to see lower variability at low spawning escapements and higher variability at high spawning escapements (Hilborn and Walters 1992). The amount of interannual variation that occurs in at-risk salmon populations is a critical factor that affects the extinction risk for the population. As interannual variation increases, extinction risk increases (Morris and Doak 2002; Lestelle et al. 2014 and 2018). The relevance of these points will be discussed later in the report.

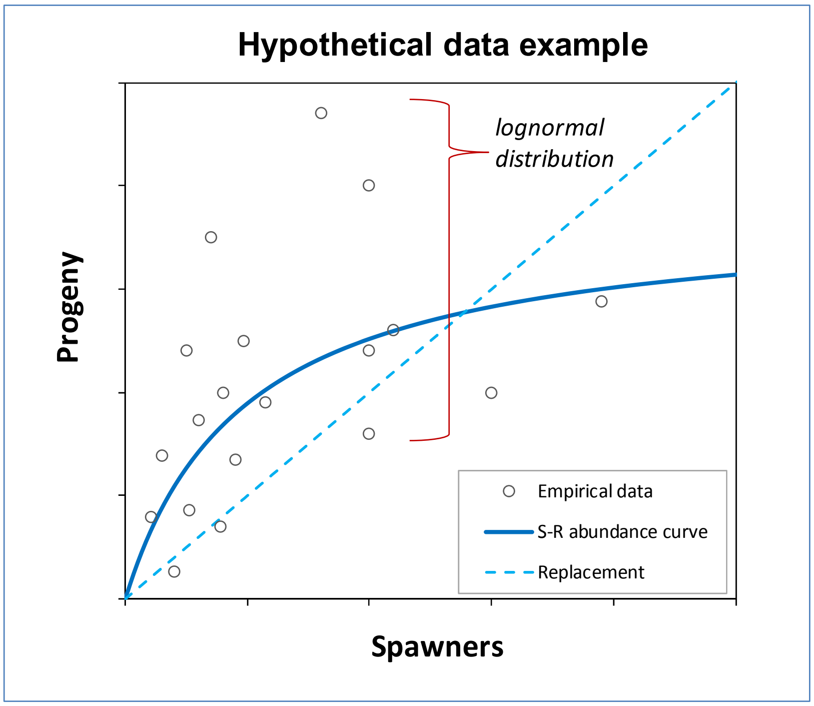

Figure 2-3. Hypothetical example of variation in progeny production around the underlying spawner-production relationship.

2.2. EDT Modeling

EDT is a suite of tools developed to provide natural resource managers with a process for organizing information and developing a scientifically credible plan for moving forward with salmonid restoration and protection (Lichatowich et al. 1995; Blair et al. 2009). The tools include an analytical model to facilitate analysis and evaluation of potential actions for restoration and protection planning. The model explicitly links actions to projected outcomes and provides a framework for decision making to help address scientific uncertainty and environmental variability (Figure 2-4).

An EDT assessment helps develop one or more operating hypotheses about why a salmon population performs the way it does within a watershed, given the conditions of that environment. The result of the assessment is a testable hypothesis to guide habitat restoration for the watershed being modeled.

The EDT model is a salmonid life-cycle habitat model that assesses the potential of habitat to support species and populations using VSP metrics. The model is designed to assess environmental constraints on a salmonid population. It predicts the ways in which salmonid populations respond to changes in the aquatic environment, allowing managers and planners to explore alternative habitat restoration strategies and potential future land use decisions. The model is also being used to assess the effects of future climate change conditions on salmonid populations for restoration planning (ASRPSC 2019).

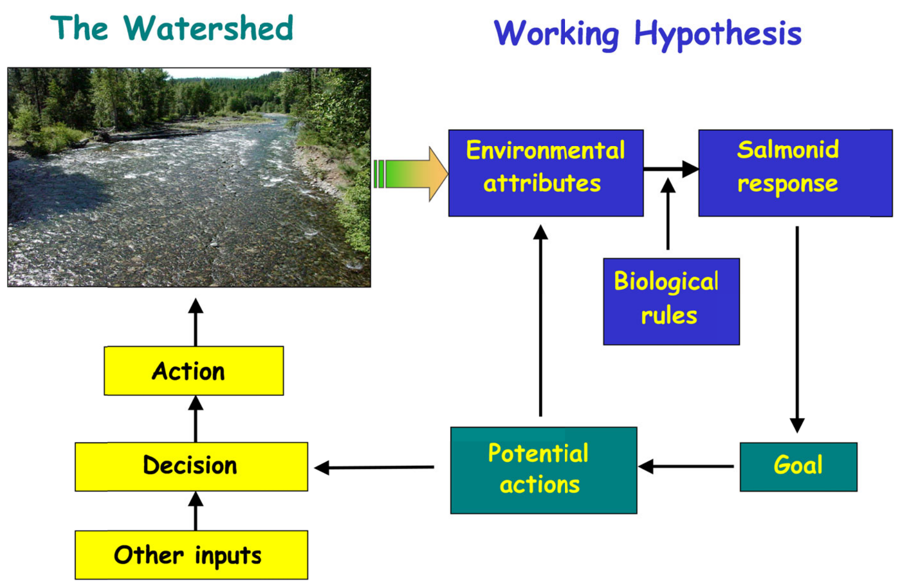

Figure 2-4. Simplified conceptual framework of the EDT model and how it is used in watershed restoration planning. The left side of the chart represents the actual watershed of interest, together with a generalized decision making process for restoration. The right side of the chart represents the modeling process of the watershed's habitats to project the performance of a salmonid population in response to the habitat condition. Modeling is used to evaluate different habitat scenarios and to compare their projected outcomes to desired outcomes.

While the model is fundamentally simple, it is computationally intricate because of the complexities of salmon life history, differing habitat requirements by life stage, and the stream reach network within a watershed. The model is based on the multi-stage B-H production model (Beverton and Holt 1957; Moussalli and Hilborn 1986; Mobrand et al. 1997).

The model is spatially structured to represent a stream network within a watershed, delineating as many stream reaches as necessary to reflect the diversity of environmental conditions present in the stream system. The reaches are connected in the model consistent with actual reach connectivity that occurs in the watershed, providing the means to model a multitude of separate, discreet life history pathways through the watershed that a species experiences. Stream reaches are delineated based on geomorphic similarities, tributary confluences, and other features expected to differentiate habitat conditions throughout the stream system.

EDT uses over 45 different environmental attributes to characterize all stream reaches. The attributes describe characteristics of stream reach size, channel slope, temperature, flow, sediment, riparian conditions, wood load, habitat types, and other environmental conditions of importance to salmon survival (Lestelle et al. 2004; Blair et al. 2009). While the full set of attributes is large and diverse, typically only a relatively small subset of these is relevant within a certain environmental setting. The full set of attributes enables the model to evaluate a broad range of stream types and environmental settings, from historical conditions largely unaltered by man to urban streams that are highly modified. The attributes are characterized for the model using a standard nomenclature for all stream reaches and across all 12 months of a year (Lestelle et al. 2004; Lestelle 2005). Attribute definitions as applied in the model are provided in Appendices B and C.

The model is rule-based. It incorporates explicit assumptions about the relationships between environmental condition and salmon survival. These assumptions define survival parameters in relation to the various attributes. The rules function in the model to estimate aspects of species-specific productivity and capacity by life stage, stream reach, and month, which are then used to project population performance for the species of interest. A rule set is essentially a synopsis of the scientific understanding of the habitat requirements of the species at each life-stage. The development and refinement of rule sets was a deliberative process of consulting with knowledgeable experts, reviewing literature on the subject, and testing (Lestelle et al. 2004; Blair et al. 2009).

A salmon population is defined in the EDT model by identifying the distribution of all stream reaches within a river system that encompass the historical spawning distribution of the species being modeled. The population is modeled using an analytical procedure that generates alternative potential pathways through the environment, called life history trajectories that could be used by the species to complete its life cycle. Trajectories are built within the model, starting with egg deposition, to simulate how fish advance through their life cycle, changing location in space and time consistent with known life history patterns for the species being modeled. Trajectories originate in all reaches encompassing the historical spawning distribution. A population is typically modeled using many thousands of unique trajectories. The trajectories include all life stages of the species in both freshwater and the ocean—finally returning to the locations of their origin to end at spawning.

The performance of individual trajectories is assessed by the model using the recursive properties of the B-H production function (Beverton and Holt 1957; Moussalli and Hilborn 1986; Mobrand et al. 1997) to compute cumulative productivity and cumulative capacity along the entire length of the trajectory, ending at spawning.

The model requires inputs of certain demographic and life history characteristics for the population being modeled: average age structure, fecundity, and migration timing patterns (i.e., adult migration, spawning, and juvenile migration timing). These inputs to the model can employ empirical data for the population if available, or lacking that, use of literature values appropriate for the population being modeled.

Population performance (i.e., encompassing all trajectories) is computed as the integration of all trajectories at spatial and temporal scales relevant to the population structure of the species. This step produces steady-state estimates of productivity, capacity, and Neq abundance for the population. Life history diversity is calculated as the proportion of all trajectories that complete the life cycle with an end of life cumulative productivity >1.0 adult returns per spawner, i.e., trajectories with a parent spawner producing more than one returning adult.

As described in Lichatowich et al. (1995), a typical application of EDT involves assessing salmon performance in a river system under two baseline scenarios: the current condition and a reference or template condition that reflects the stream in its unaltered state. The template condition is usually derived to represent our best understanding of the historical conditions prior to Euro-American settlement. Comparing performance under the two baselines is the basis of diagnosing the factors that affect current performance relative to the historical condition.

The central part of the diagnosis is given in the form of a quantitative limiting factors analysis (LFA). The LFA identifies the relative importance of different groups of stream reaches (geographic areas) for restoration or protection. Reaches identified as having high restoration importance are those that were historically productive for one or more life stages of the population but have since been altered to a much reduced productive state. If restored, these reaches would provide high potential benefit to the population. In contrast, reaches identified as having high protection importance are those that are currently functioning in a way that still contribute benefits to existing population performance but if further degraded the population would suffer greater loss.

The LFA also identifies the relative importance of different habitat survival factors that have contributed most to the decline of a salmon population. These factors are the ones that should primarily be considered in restoration and recovery. In effect, the survival factors are a synthesis produced by the model of how the many environmental attributes combine to affect productivity and capacity; the factors are expressed in terms that identify the types of environmental attributes that produce the effect on biological performance. Habitat survival factors summarized by the model are listed and defined in Appendix A.

It is worth noting here that stream reaches that have both restoration and protection benefits are likely the best candidates where restoration should be focused. These are areas that have importance for restoration but they are also at least partially functioning ecologically currently—which means that they are not so degraded to make restoration extremely difficult to achieve.

The diagnosis serves as the basis for developing potential restoration scenarios to address limiting factors. The model can then be used to evaluate the scenarios and assess potential changes in future salmon performance if actions were to be developed and implemented consistent with the modeled scenarios.

The results from these analytical steps can be used to identify types of actions, where they should be implemented (if feasible), and what environmental factors should be targeted. Potential actions identified in this step would comprise candidate actions, which can then be further evaluated as needed. Although specific actions were not evaluated as part of this project, the EDT model has been used to analyze a wide range of potential actions. Actions are modeled by making reasonable assumptions about how effective the actions would be in changing the environmental characteristics (through the attributes) back toward historical conditions. The modeling process is then applied to project the effect on salmon performance. Output from this process can be used to rank and prioritize candidate actions based on projected benefits to salmon populations.

2.3. Restoration Scenarios

Several generalized restoration scenarios were developed for analysis using the EDT model. The purpose of this part of the assessment was to help understand and evaluate the kinds, magnitude, locations, and intensities of actions that would be required to produce substantial changes in performance of the three Scott River salmon populations. The scenarios were developed as “what ifs.”

The scenarios were developed around some specific themes of restoration actions that might be considered for the subbasin. Each theme for restoration was meant to represent a category of action types that could be implemented. The categories consisted of restoration of surface flow that could result from a reduction of groundwater pumping, riparian restoration, floodplain channels restoration, and a combination of those three categories.

Details for how the restoration scenarios were developed are given in Section 6.1.

3. Historical Overview

This section provides an overview of the known or inferred characteristics of the Scott River subbasin and the three salmon populations of interest to this assessment. I review the major environmental alterations that were made to the subbasin over the past roughly 200 years that have resulted in its current condition. Similarly, I describe relevant characteristics of the salmon populations as we can reasonably assume existed over this period of time. This overview gives context and background information for performing the assessment and for helping to judge its accuracy and potential application.

3.1. Scott River Subbasin

This section describes general characteristics of the subbasin, a history of the major alterations that have occurred to the in the subbasin since the mid-1800s, and a summary of how flow patterns have been altered in the subbasin.

3.1.1. Subbasin Description

The Scott River is one of four major tributaries of the lower Klamath River (downstream of Iron Gate Dam), entering the Klamath at River Mile (RM) 143 at an elevation of 1,580 ft. The Scott River subbasin drains an area of 812 mi^2 (Figure 1-1). The river originates in forested headwaters of the Marble, Scott, and Trinity mountains, meanders through the broad, agriculturally rich Scott Valley, and then flows through the steep Scott River Canyon before joining the Klamath River (NRC 2004). The mountainous areas within the subbasin are largely national forest lands. The subbasin has substantial variation in geology, geomorphology, and climatology (SRWC 2006).

The subbasin is dominated by a Mediterranean climate characterized by warm, dry summers and cold, wet winters (ESA 2009). Precipitation is mainly concentrated in the winter months and falls primarily as rainfall on the valley floor, while significant snowfall occurs in the surrounding mountains, resulting in snowmelt runoff during the early spring months (Deas and Tanaka 2006). Average annual precipitation for the entire area is about 36 in, yet annual rainfall, snowfall, and temperature can vary widely from one year to the next and from one part of the watershed to another. The valley floor lies between elevations of 2,700 and 3,000 ft. The western mountains rise abruptly to 8,000 to 8,500 ft. These ranges exert a strong orographic effect on incoming storms, which allows the higher elevation mountains (along the west and south), to receive 60 to 80 in of precipitation annually. In contrast, the rain shadow effect of the mountains to the west reduces the amount of annual precipitation to 12 to 15 in on the east side of the watershed (SRWC 2006). About 75 to 80% of the precipitation occurs from October through March (ESA 2009).

The geology of the subbasin is complex with several identified formations and rock types (Mack, 1958; North Coast Regional Water Quality Control Board [NCRWQCB] 2005). These vary by subwatershed within the subbasin and are a primary factor in determining the nature and magnitude of geomorphic processes and sediment delivery under natural conditions, as well as sediment delivery in response to human activities (ESA 2009).

A significant portion of the subbasin is underlain by various types of granitic bedrock, exposed primarily in the mountains paralleling the west side of the Scott Valley. Notably, where weathering is severe, the “decomposed” granitic soils are highly susceptible to dry ravel, rill and gully erosion, debris slides, and debris torrents. Soil erosion and fluvial transport in disturbed areas (e.g., burned landscapes) are the most common sediment transport and delivery processes in areas of decomposed granitic soils. Soils derived from the granitics are noncohesive and usually highly erodible. About 56,900 acres of granitic soils are found in the Scott River watershed, mainly on the south and west sides of Scott Valley (Sommarstrom et al. 1990).

The principal groundwater feature in the subbasin is the Scott River Valley Groundwater Basin (Groundwater Basin). The Groundwater Basin underlies the alluvial floodplain and is approximately 28 mi long, 0.5 to 4 mi wide, and nearly 100 square miles in surface extent (CDWR 2004). Within the Groundwater Basin, stream channel, floodplain, and alluvial fan deposits are the primary water-bearing formations (ESA 2009).

In the valley, groundwater has a strong influence on the amount and quality (i.e., temperature) of Scott River flow. The seasonal fluctuation of the groundwater table locally determines whether portions of the Scott River are being supplied by groundwater (“gaining stream”) or are infiltrating surface flow into the groundwater aquifer (“losing stream”). During the winter and spring the aquifer is recharged by the river and percolated precipitation. Once river flow subsides, the river typically changes to a gaining stream as stored groundwater enters the stream channel (ESA 2009). In dry years, winter and spring flows are not sufficient to fully recharge the Scott River Valley Groundwater Basin, the water table falls below the elevation of the channel bed, and parts of the river can go dry (NCRWQCB 2005; ESA 2009).

The hydrograph of the Scott River exhibits two seasonal pulses. A winter pulse is caused by high precipitation from December through early March; this pulse is highly important geomorphically because it accounts for the annual sediment transport (Sommarstrom et al. 1990). The second pulse is caused by the spring snowmelt, which begins in late March and in wet years continues through June (NRC 2004).

It is likely that in all but the most severe drought years the mainstem river provided important and productive habitat for juvenile salmonids, including coho salmon, throughout the summer, especially in the sloughs and pools of the numerous beaver dams that once were characteristic of the streams on the valley floor (CDFG 1979; NRC 2004).

3.1.2. History of Alterations

The entire Scott River system, particularly within its large valley, has undergone enormous changes since the mid-1800s. Watershed ecological processes have been significantly altered as a result of intensive human-related actions over this time in conjunction with occasional intense flooding events and periodic droughts. Combined, these events have modified the river system's hydrology, sediment transport, physical habitat structure, temperature characteristics, riparian structure, and aquatic and semi-aquatic biota.

The history of these alterations to the subbasin is well documented in many reports and historical and scientific papers (e.g., CDWR 1965; Sommarstrom et al. 1990; NRC 2004; ESA 2009). Notable events in this history are summarized briefly here to provide some context and background to help the reader understand the importance of these alterations to this assessment.

The subbasin has been inhabited by Native American people for millennia (USFS 2000)—but changes in the watershed due to human actions were likely extremely small prior to the arrival of Euro-Americans in the early to mid-1800s – though the extent of these changes is unknown according to Sommarstrom et al. (1990).

In 1827, a party of Hudson's Bay Company trappers came down the Oregon Coast and passed through Scott Valley on their way to the Sacramento Valley. They called it "Beaver Valley", and apparently the river Beaver River, due to the large number of beaver inhabiting the area (CDWR 1965; Sommarstrom et al. 1990). Sommarstrom et al. (1990) stated regarding the activity of the trappers in the 1830s and some of the effects that it must have caused:

> *"They reportedly trapped 1800 beaver on both forks of the Scott River in one month. It was "the richest place for beaver I ever saw", claimed one trapper many years later. He also described the Scott Valley as all one swamp caused by the beaver dams (Wells, 1881). While not all of the beaver were taken, this major removal likely had a significant effect on the Scott River and its tributaries. Beaver dams slow the movement of water, sediment, and streamside vegetation out of watersheds. As a result, more water is stored, the ground water is recharged, and more diverse vegetation grows along streams."*

NRC (2004) described the general pattern of beaver trapping in the Klamath River basin during this time period. Attempting to discourage Americans from laying claim to the region, the Hudson's Bay Company's written policy was to trap fur-bearing animals from streams south of the Columbia River to extinction. In 1828, Peter Skene Ogden, the trapper who opened up much of the Klamath region to white exploration, followed that policy. He wrote of the region that "almost every part of the country is now more or less in a ruined state, free of beaver" (Ogden 1971 as cited in NRC 2004).

There is no doubt that the large-scale, rapid removal of beaver from the valley quickly caused simplification of channel structure and loss of floodplain water storage throughout the valley and into the forks (Sommarstrom et al. 1990; ESA 2009)—loss of beaver is a major cause of incision in low gradient streams without bedrock controls to prevent incision (Naiman et al. 1988; Beechie et al. 2008; Pollock et al. 2014).

ESA (2009) summarized the likely effects to the Scott Valley as a result of beaver trapping:

- A rapid incision into the accumulated fine sediment of the ponded stream reaches, turning them into gullied or entrenched stream channels;
- Larger, flashier floods, increased sediment yield from unstable and eroding streambeds and banks, and less diverse habitat;
- A reduction in riparian and slow-velocity habitats; and
- A reduction in summer baseflows and associated water storage capacity.

Where once the valley would have been rife with beaver pond complexes and associated wetlands, ponds and swamps—and a multi-threaded Scott River channel—the river apparently very quickly devolved into a single threaded channel largely removed from the complexity of its surrounding floodplain (Sommarstrom et al. 1990). In May 1855, one observer described the Scott River in the valley as "from thirty to forty yards in width, deep in many places, with a current of from five to seven miles per hour" (Metlar 1856, cited in Sommarstrom et al. 1990). That description fits a swiftly flowing, single threaded river—deep in places—moving at 7 to 10 ft per sec. The relevant point is that the river was apparently undergoing an evolution from a multi-threaded channel to more of a single threaded channel, downcutting into the valley floor.

Within a relatively short time after beaver removal, another change swept through the Scott River subbasin. Gold was discovered in 1851. Mining was particularly destructive to fish habitat in the Klamath River basin, and especially in the Scott River subbasin (NRC 2004). Gold-bearing placer deposits were blasted with water to wash away gravel, sluicing huge volumes of sediment into the stream system; streams were diverted and channelized. Major changes occurred to the mainstem Scott River, South Fork, and to Oro Fino, Shackleford, and French creeks. Large Yuba dredges, operating in 1934-1950 (Sommarstrom et al. 1990) excavated 50-60 ft below the mainstem river bed in the upper valley, creating tailings piles in excess of 25 ft high – all of which is still present today. Surveys by Taft and Shapovalov (1935) noted the severe damage to fish habitat caused by the dredging.

Mining facilitated other major alterations—numerous ditches were constructed along the margins of the valley to intercept tributary streamflows to support the mining. These ditches eventually became the sources of irrigation water to support early agricultural development in the valley (NRC 2004).

Other changes to the subbasin followed, including large-scale timber harvest. By 1880, there were 11 sawmills operating in the valley cutting 3.5 million board feet per year (Wells 1881, cited in Sommarstrom et al. 1990). In 1958, two sawmills were operating in Scott Valley with a combined capacity of 40 million board feet per year (CDWR 1965). Logging activity reached a peak in the 1950s (Sommarstrom et al. 1990). About 40% of the subbasin that is underlain by decomposed granitic soils was harvested in 1958-1988; more than 288 mi of logging roads and 191 mi of skid trails were constructed (USFS data, Sommarstrom et al. 1990). Road construction and skid trails have been a major source of fine sediment in the subbasin, particularly on decomposed granitic soils. All of these activities had adverse effects on spawning and rearing habitat of salmon in the subbasin (West et al. 1990).

The rapid development of agriculture in the valley brought more expansive changes to the valley. Farming and ranching have been an important part of the Scott Valley economy since the mid 1800s (ESA 2009). As agricultural practices expanded, actions were taken to remove native riparian vegetation, drain wetlands, channelize streams, and place streambank protection structures to prevent channel migration (Sommarstrom et al. 1990; ESA 2009). Attempts at protecting streambanks from erosion and avulsion often accelerated bank erosion. Due to problems created by earlier channelization work, more work with extensive revetment (rock and biotechnical), bank armoring, and channel reshaping took place during the 1950s and 1960s in an effort to further stabilize the river (Ayres and Associates 1999, cited in ESA 2009). Large stretches of the river and some of the tributaries in the valley are now entrenched and confined by these bank stabilization efforts. These practices on some Scott River tributaries have continued into recent years (ESA 2009).

To support the rapid expansion of agriculture in the valley beginning in the 1850s, water diversion was required. NRC (2004) stated at the time of that report that there were 153 registered diversions in the valley. All surface water rights in the subbasin upstream of the USGS gaging station (10 mi downstream from Fort Jones) are adjudicated under three decrees. The total allotment of water provided by these decrees is greater than the average monthly flow of the Scott River from June through December, based on 64 years of record (ESA 2009). Since 1989, Scott River, French Creek, Kidder Creek, Shackleford Creek, and Mill Creek have been considered “fully appropriated” by the State Water Resources Control Board (SWRCB) (SRWC 2006).

Over 200 miles of ditches and canals divert and distribute water from the Scott River and its tributaries to users throughout the subbasin (ESA 2009). Virtually all diversions within the subbasin have now been outfitted with fish exclusion screens – but it is important to note that there is no consistent screen monitoring and maintenance to ensure that bypass flows around these screens are sufficient to sustain rearing juvenile coho salmon and their habitat downstream (NMFS 2014). It is also important to recognize that the screening of diversion ditches and canals is a relatively recent action compared to the long history of diversions without these devices.

There are no large surface water storage facilities within Scott Valley, though there are several small local impoundments (Deas and Tanaka, 2004). The largest water storage location in the watershed is the aquifer beneath the alluvial valley (ESA 2009).

Pumping of groundwater from the alluvial aquifer began prior to the 1960s but increased dramatically since then (ESA 2009). In 2000, CDWR (as cited in SRWC 2006) estimated that 45% of the irrigated acres in the Scott Valley were using groundwater, compared to just 2% in 1958 (SRWC 2006, summarized in ESA 2009).

ESA (2009) stated that an increase in the volume of water being utilized in irrigation over this period consisted almost exclusively of groundwater. Van Kirk and Naman (2008) concluded that there has been an increase in total irrigation withdrawals in the Scott Valley of 115% since 1953. Those authors noted that the increase in withdrawals was accompanied by an 89% increase in irrigated land area. Van Kirk and Naman (2008) also noted that an important shift in irrigation practices in recent decades was the change from flood to sprinkler irrigation, which increased efficiency but reduced groundwater recharge. At the time of their analysis, these authors stated that a large proportion (80% or more) of water used for irrigation in the valley comes from groundwater.

S.S. Papadopulos & Associates (2012) estimated using modeling that the net increase in groundwater pumping between the 1980s and year 2000 resulted in a corresponding depletion impact of approximately 16 cfs to the river in the lower valley during the late summer season. No estimates were made for the effect of increasing pumping that occurred between the 1960s and 1980s. Papadopulos also noted that the modeling results indicate that despite the cessation of pumping during the non-irrigation season and the occurrence of recharge, that stream depletion impacts continue to accumulate over time and have the potential for significantly higher impacts than are seen within the first or same season of pumping (see Hathaway 2012).

Unlike some of the surface diversions in the Scott River subbasin, there is no regulation, management, or quantification of the extraction of water from wells, other than the minimal regulation that occurs within the "interconnected zone" specified in the Scott River Decree (Naman 2005, cited in ESA 2009).

CDFW (2017), in assessing instream flow criteria for Scott River, stated that during the summer, large portions of the mainstem Scott River within the valley become completely dry, leaving only a series of stagnant isolated pools inhospitable to salmonids.

3.1.3. Changes in Flow Patterns

As described earlier, the Scott River flow regime has a general, seasonal pattern that is consistent among years in all but the most extreme water years. This pattern shows two seasonal pulses—a winter pulse and a spring snowmelt pulse. In late summer, flows decrease to low levels in August and September as a result of the natural runoff patterns in the subbasin, from both rain and snow, combined with water withdrawals for irrigation during late spring, summer, and early fall.

Surface water diversions are extensive throughout most of the subbasin. The large majority of these diversions began in the mid to late-1800s and the early part of the 20th century (CDWR 1965). Hence the patterns of water diversion and how they would have been reflected in the hydrograph for Scott River were well established prior to when USGS began operation of the gauging station located near the top end of canyon in late 1941.

Streamflows in the mainstem Scott River are markedly lower in late summer since the late-1970s compared to the 1940s to early 1970s (Drake et al. 2000; Van Kirk and Naman 2008; Foglia et al. 2013). Van Kirk and Naman (2008) attributed the decline to both climate-related effects and to an increase in groundwater extraction.

I examined the flow data from the Scott River USGS streamflow gauge at Ft. Jones to assess the patterns of change from 1941 to 2020. I used a common method applied in meteorology and climatology to visualize the data, which is to plot the deviations (referred to as anomalies) from the long-term average value in the time series (e.g., Hare and Mantua 2001)—this method is particularly effective at detecting patterns in these kinds of data. Daily average streamflows at the gauging station were calculated by month and year, beginning with oldest data (1941). The long-term monthly averages were calculated and these served as the base level for computing deviations from the mean. Standard deviations were calculated for each month for the entire data series. Deviations from the long-term average for the month were then plotted. Positive deviations mean that the average for a month and year is larger than the long-term average; negative deviations indicate that the average for a month and year is less than the long-term average.

Figure 3-1 displays the time-series patterns for deviations from long-term average streamflows for August and September beginning with 1942 (no data were available for these months for 1941). The results clearly show a shift in mean daily flows in August and September to reduced flows beginning sometime in the 1970s and continuing to the present. The timing in this shift coincides with increased groundwater pumping that occurred at that time. It should be noted that summer flows were abnormally high in 1983 due to an exceptionally wet winter and spring.

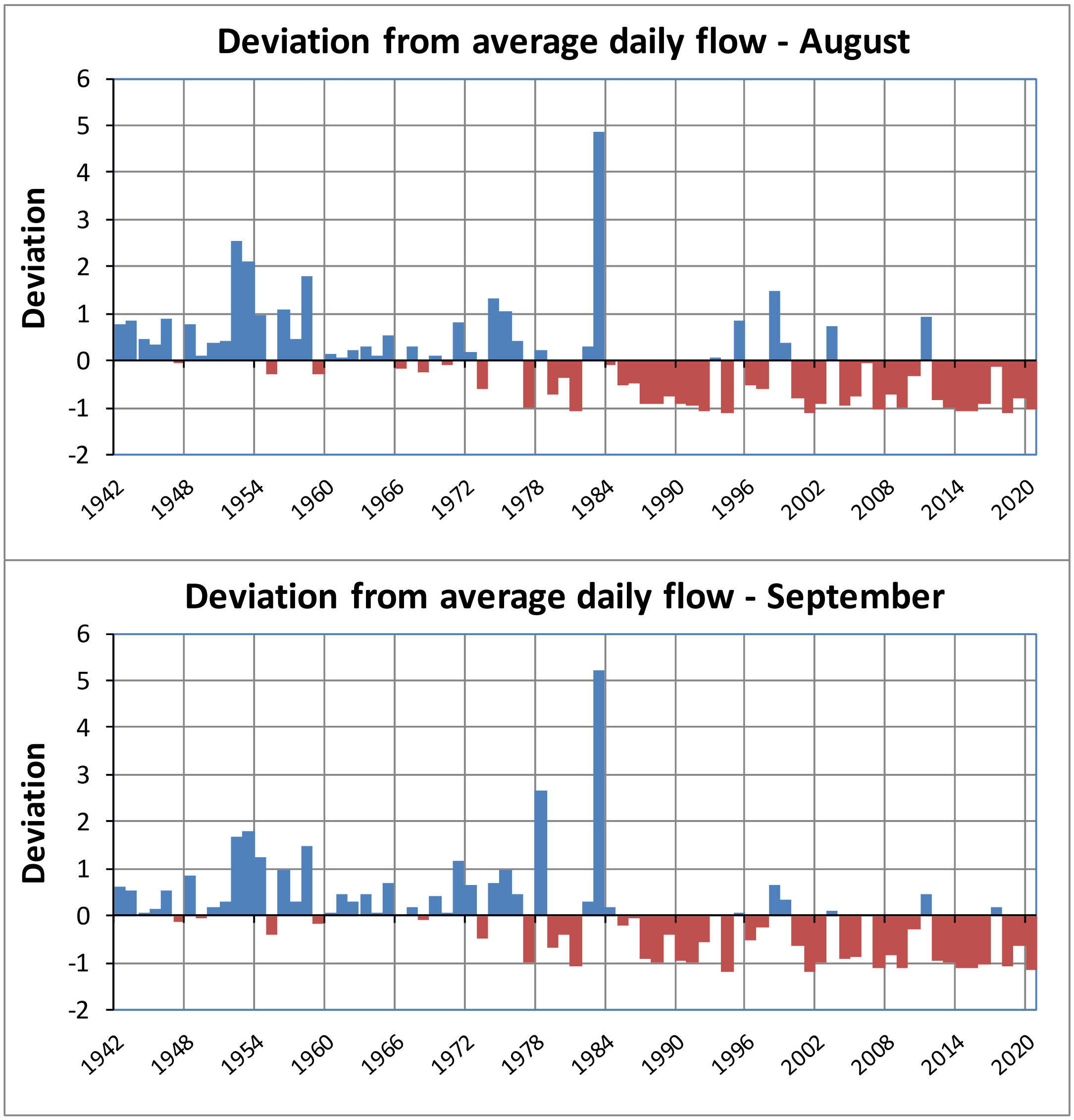

Figure 3-1. Deviations from the long-term average daily flow by month for 1942-2020 at the Ft. Jones USGS gauging station. Deviations are expressed as standard deviations from the long-term average.

Figure 3-2 shows the average daily flows by month and year for August and September for the time series, color coded to generally depict when the shift to lower flows occurred in the 1970s. For this plot, I assumed the shift occurred in 1977, which corresponds well with the patterns in Figure 3-1. A shift to lower flows beginning about that year is plainly evident in the figure. The data plots in the figure also identify years when drought conditions were recognized to be occurring in California—shown with filled circles in the plots. I used information from two sources to identify drought years; these sources are found at

https://www.drought.gov/drought/states/california

https://en.wikipedia.org/wiki/Droughts_in_California

Although drought years were more common in the period beginning in 1977 than in prior years, there were also drought years prior to 1977. The overall patterns for years beginning in 1977 show an unmistakable shift to much reduced streamflows in those years, continuing to the present time. Surface water withdrawals on the scale that occurs in the Scott River subbasin combined with extensive groundwater pumping clearly reduces river flows to extremely low levels. Drought conditions worsen these conditions further.

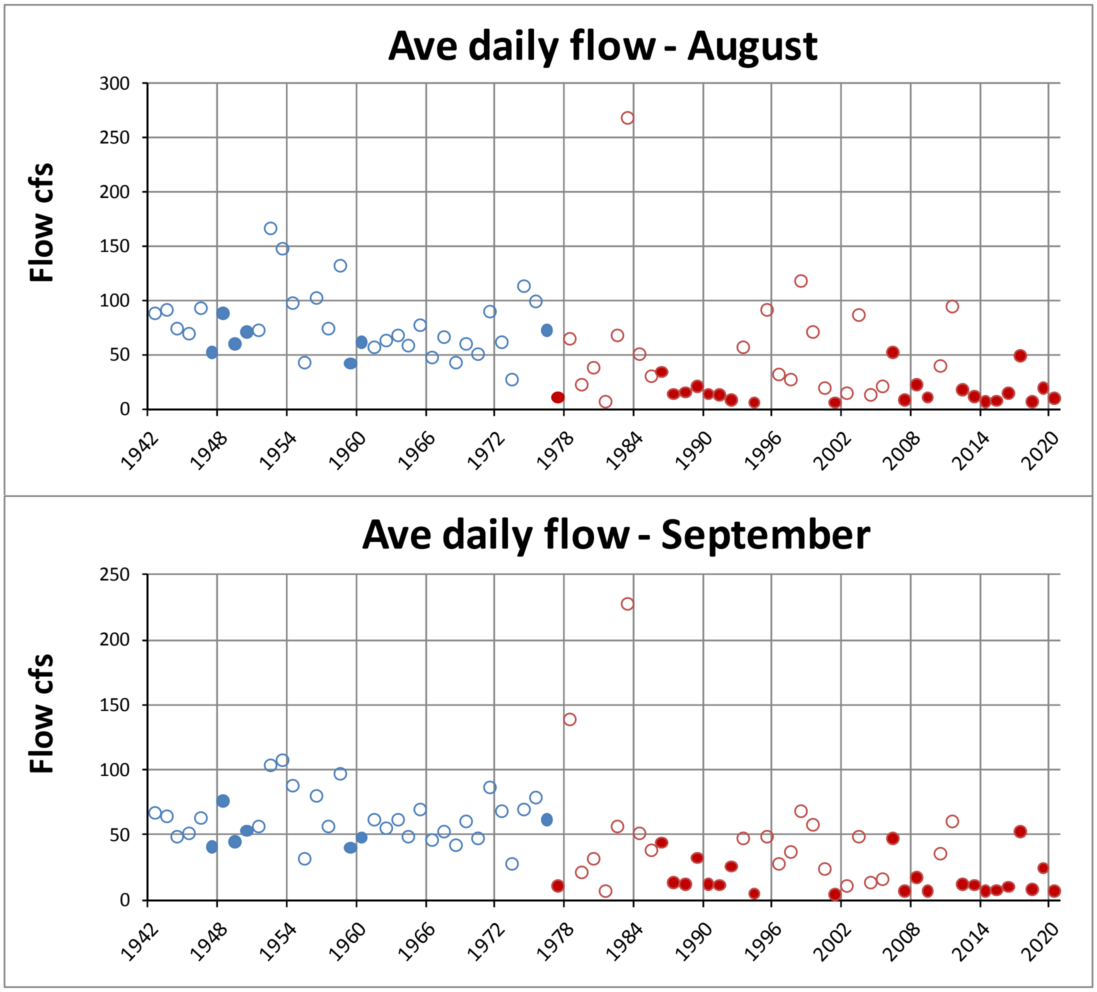

Figure 3-2. Average daily flow for August and September for 1942-2020. Circle colors change to red beginning in 1977, generally corresponding to when groundwater pumping is considered to have increased significantly. Filled circles depict years considered as drought years in California.

Table 3-1 provides daily average flows computed for two different periods that were used as reference conditions in the analysis done in this report to represent (1) the prepumping period (1942-1976) and (2) the current baseline period.

Table 3-1. Average daily flow (cfs) for two periods at the USGS Ft. Jones gauge station: 1942-1976 represent the prepumping period and 2003-2017 representing current conditions with a mix of water year types.

Years	Average flow (cfs)	
	Aug	Sep
1942-1976	77.1	62.0
2003-2017	30.6	23.7

ESA (2009) noted that the persistence of low baseflow can exert an effect over an increasingly larger geographic area, such as adversely affecting the condition of the entire riparian corridor. Lowering the streamside water table within the corridor will result in a continued loss in stabilizing riparian vegetation and subsequently to increased bank erosion and channel incision during high-flow periods.

Figure 3-2, combined with all of the other alterations that have occurred to the subbasin, suggests that the natural resiliency of the watershed's hydrological system and its related ecological processes, have been reduced to a minimal state. There appears to remain little or no reserves in the system to ameliorate the effects of the current drought that has gripped the region.

3.2. Salmon Populations

The Scott River subbasin historically supported three salmon populations: coho, fall Chinook, and spring Chinook salmon. The subbasin historically also supported a substantial population of steelhead—and still does.

3.2.1. Coho Salmon

Scott River coho are identified as a distinct population within the Southern Oregon/Northern California Coast (SONCC) Evolutionarily Significant Unit (ESU) of coho salmon (Williams et al. 2006). The National Marine Fisheries Service's (NMFS) listed the SONCC ESU of coho salmon as a threatened species under the Endangered Species Act (ESA) in 1997, a decision that was reaffirmed in 2005 (NMFS 2014).

NMFS (2014) concluded that the Scott River coho population is a core, Functionally Independent population within what it calls the Interior Klamath River diversity stratum; historically having had a high likelihood of persisting in isolation over 100-year time scales (Williams et al. 2006). As a core population, it likely served as a source of spawner strays for nearby populations in the Klamath basin.

The characteristics of the historical Scott River subbasin indicate that it was very productive for coho salmon prior to settlement by non-Indians. The large Scott River valley, with its extensive floodplain and riverine features shaped by abundant beaver over millennia, would have encompassed ideal physical habitat for juvenile coho salmon. These habitat features within the valley, in combination with the steeper upper river and adjacent tributaries flowing into the valley, would have supported a large coho population. Low gradient streams inhabited by abundant beaver are particularly productive for coho (Pollock et al. 2004; Lestelle 2007).

Well-documented estimates of the historical coho abundance in the Scott River subbasin do not exist (NRC 2004). A report by the USFWS (1979), citing USFWS (1960) and Holmberg (1972), listed the mean historical annual spawning escapement of coho salmon in the Klamath River system at 20,000. The source documents for the 20,000 number are unavailable to me so I cannot verify the exact geographic range or historical period to which that number was meant to be applied. As will be seen below, there can be little or no doubt that this 20,000 figure is much too low to represent the Klamath basin-wide production of coho salmon prior to non-Indian settlement. While the contribution of the Scott River subbasin toward the basin-wide spawning escapement would have been much less than 50%, the Scott River spawning escapement alone likely often exceeded 20,000, as will be demonstrated below.

Lestelle (2013) applied four methods to estimate the historical coho salmon abundance for the Scott River subbasin, referred to as follows:

1. Ackerman method (based on Ackerman et al. 2007);
2. ONCC TRT extrapolation method (based on Lawson et al. 2007)[4];
3. Bradford method (based on Bradford et al. 1997); and
4. EDT extrapolation method (based on application of EDT modeling in Washington State rivers).

Table 3-2 summarizes the estimates of historical smolt capacity for the Scott River obtained with the four methods. Two estimates were made using the EDT regressions, one based on the watershed area regression and another based on the stream length regression. The estimates for all methods ranged from 222,700 to slightly over 3,000,000 smolts.

Table 3-2. Summary of estimated average historic smolt capacities of coho for the Scott River subbasin based on different methods of estimation. It is recognized that the Ackerman estimate is not a true estimate of historical capacity, though it does appear to contain aspects of both the historical and current environmental conditions. From Lestelle (2013).

	Method	Mean smolt capacity
1	Ackerman	222,700
2	ONCC TRT regression	3,010,800
3	Bradford regression [1/]	506,700
4a	EDT regression - watershed size	892,200
4b	EDT regression - stream length	525,100

Lestelle (2013) discussed each of the methods and pros and cons of each. He concluded that the best estimate was the one derived with the EDT regression using stream length, i.e., approximately 525,000 smolts. Based on relationships between summer flow and coho smolt yields observed in Washington State, he broke the point estimate of smolt capacity into three levels that would be expected when summer low flow conditions occurred in dry, average, and wet years (as low, average, and high), and applied a range of marine survival conditions (low, average, and high) to produce an estimated range of expected adult returns to the Scott River subbasin (Table 3.3). At an expected average marine survival of

[4] / Oregon and Northern California Coast (ONCC) Technical Recovery Team.

4% under an average summer flow condition, expected adult return was estimated to be about 21,000 fish. Estimated spawner abundance under the different flow and marine survival scenarios ranged from about 3,300 to 58,000 fish – a range not unexpected with this amount of interannual variation in flow and marine survival.

Table 3-3. Estimated historic adult coho run sizes returning to the Scott River subbasin under three flow scenarios and three marine survival scenarios. Table taken from Lestelle (2013).

Summer flow scenario	Marine survival scenario		
	Low (1%)	Average (4%)	High (8%)
Low	3,265	13,060	26,119
Average	5,251	21,004	42,008
High	7,237	28,948	57,897

Little or no data exists to document coho abundance in the Scott River subbasin in the second half of the 20th century though it was known that habitat conditions had deteriorated significantly (CDFG 2004). CDFG estimated the abundance of coho salmon spawners in the Scott River watershed during the early 1960s at 800 fish (CDFG 1965 cited in CDFG 2004), but it is unknown how that estimate was derived. It bears noting that if 800 spawners returned to the Scott River at that time, then the total number of adult fish that was actually being produced was much larger, likely by a factor of at least 2X because of fishery interceptions in the ocean and river.

CDFG initiated smolt trapping on the lower Scott River (RM 4.7) to estimate coho smolt yield from the subbasin beginning in 2003 (Debrick and Stenhouse 2014). Some interruptions in estimation have occurred since then but generally estimates exist for most years (15 years) (Table 3-4). The geometric mean number of smolts estimated to have emigrated from 2003 to 2019 was approximately 8,400 with a range of 353 to 95,815. No estimates were made in 2004 and 2017. Smolt estimates for 2006-2019 are from Massie and Patterson (2019). Smolt estimates for 2003 and 2005 are adjusted from numbers given in Debrick and Stenhouse (2014)—it was apparent that some kind of adjustment had been made in more recent reports to smolt numbers listed in Debrick and Stenhouse (2014) for 2006-2014 because all of the numbers had been adjusted upwards. I correlated the estimates from Debrick and Stenhouse (2014) and Massie and Patterson (2019) and obtained a correlation coefficient of 1.0 (which confirms that an adjustment had been made). I then used that correlation to compute adjusted numbers for 2003 and 2005.

Table 3-4. Estimated numbers of coho smolts emigrating from the lower Scott River and adult coho spawners returning to the Scott River subbasin for 2003 to 2019. Blank cells indicate no data exists for those years. See text for sources. Smolt estimates for 2003 and 2005 were adjusted from numbers given in Debrick and Stenhouse (2014) as was apparently done for several other more recent estimates (see text).

Year	Smolts	Adult coho
2003	42,190	
2004		
2005	1,780	
2006	95,815	
2007	3,931	1,622
2008	1,142	58
2009	73,232	75
2010	3,257	913
2011	353	344
2012	63,135	186
2013	9,283	2,631
2014	6,734	383
2015	8,758	188
2016	3,372	226
2017		364
2018	14,628	712
2019	15,707	326
Min	353	58
Max	95,815	2,631
Geometric mean	8,398	356

CDFG began to use a video fish counting weir to estimate spawning escapement into the Scott River subbasin in 2007 (for the 2007-08 spawning season; Knechtle 2009). Estimates have been made in all years since then (Table 3-4). The video weir is located at approximately RM 18.2 on the Scott River (near the downstream edge of the valley). The geometric mean number of adult coho (assumed to be age-3 fish) estimated to enter the Scott River subbasin from 2007 to 2019 was 356 fish with a range of 58 to 2,631. CDFW also estimates the number of spawners that spawn downstream of the weir and these estimates are included in the totals reported here.

Two characteristics of the patterns of smolt and adult production since 2003 are important to note. The first is the extreme variation in interannual production levels, both in outmigrant smolts and adults passing the counting weir. The ratio of the maximum to minimum production levels over this period for smolts and adults has been 271 and 45, respectively. It is useful to compute the number of smolts produced per adult parent from Table 3-4 and examine the pattern in relation to the spawning escapement. Virtually all coho populations for which good time series data exist that I am familiar with exhibit consistent curvilinear patterns with declining smolts/spawner as spawning escapement increases. Two examples are shown in Figure 3-3 – one for a small stream in Puget Sound and the other for a river on the outer coast of Washington – many other similar examples exist (e.g., Salo and Bayliff 1958; Lestelle et al. 1984). The patterns seen in the figure reflect the operation of strong density dependence for coho, which is common for stream dwelling salmonids that do not migrate quickly to sea (Chapman 1966; Fraser 1969). In contrast, the pattern seen for Scott River coho is starkly different (Figure 3-4). It reflects a strong operation of density-independent mortality with high interannual variability and little or no density dependence. Such a pattern indicates that the intrinsic productivity parameter of the underlying S-P relationship for this population—operating in conjunction with significant interannual variability—is especially important to population performance.

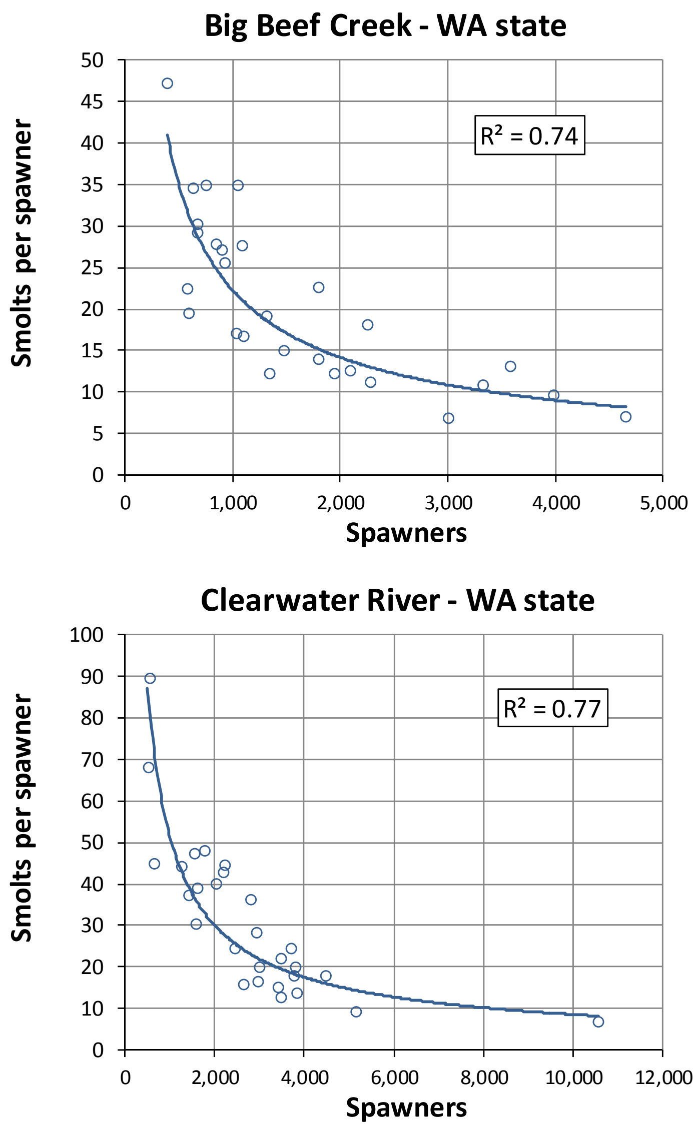

Figure 3-3. Smolts per adult spawner for coho spawners in Big Beef Creek (Puget Sound region) (data from Clayton Kinsel, WDFW, pers. communication) and in the Clearwater River (Olympic Coast, WA) (data from Quinault Indian Nation; see Lestelle 2009). Data used to construct the graphs are given in Table 3-5.

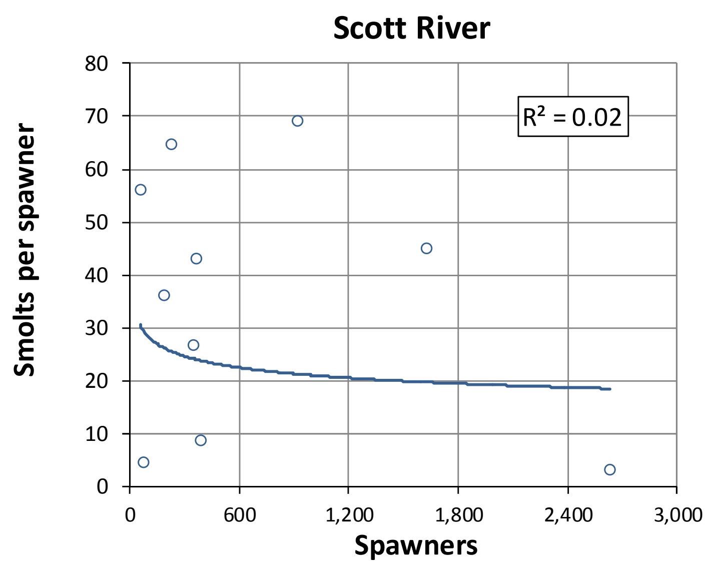

Figure 3-4. Smolts per adult spawner for coho spawners in the Scott River subbasin. Values calculated with data listed in Table 3-4 and given in Table 3-5.

The second characteristic in production patterns evident over much of the time period is a difference among the three brood lines (or brood year lineages) in the population. Three distinct brood lines exist because of the 3-year life cycle of the majority of maturing coho salmon (essentially all females are age-3 fish) (Figure 3-5). This pattern has been evident for both smolts and adults until very recently. A strong brood line is evident in the data starting with brood year 2001, which is the year that spawners produced the smolt outmigration in 2003. Whether this pattern existed prior to brood year 2001 is unknown. This brood line includes brood years 2001, 2004, 2007, 2010, and 2013 – but for brood year 2013 spawner abundance was high but smolts were not. The smolts for brood year 2013 emigrated in 2015, when smolt yield was much reduced. The adults that spawned in 2013, and their progeny, are known to have been affected by severe drought conditions that affected spawning distribution in the valley. A rescue operation was attempted in summer 2014 to capture large numbers of age-0 juveniles in the mainstem Scott River and relocate them to tributaries upstream of dry reaches (CDFW et al. 2015). Despite this effort, survival of age-0 juveniles was apparently poor (CDFW 2016).[5] The strength of the strong brood line appears to have been broken as a result (Figure 3-5).

[5] / Knechtle and Chesney (2017) estimated that 226 adult coho returned to the Scott River subbasin in 2016 from brood year 2013. This low number of adult returns on what had been the strong brood line is consistent with the view that the survival of age-0 juveniles moved during the rescue operation was poor.

Table 3-5. Estimated coho spawners (Sp), resulting smolts (Sm), and smolts produced per spawner (Sm/Sp) for Big Beef Creek (Puget Sound) (data from Clayton Kinsel, WDFW, pers. communication), Clearwater River (Olympic Coast) (data from Quinault Indian Nation; see Lestelle 2009), and Scott River (see Table 3-4). Data are listed by brood year (BY). For Scott River, for example, 1,622 adults spawned in 2007, producing 73,232 yearling smolts in 2009, yielding 45.1 smolts per spawner.

Big Beef Creek				Clearwater River				Scott River			
BY	Spawners (Sp)	Smolts (Sm)	Sm/Sp	BY	Spawners (Sp)	Smolts (Sm)	Sm/Sp	BY	Spawners (Sp)	Smolts (Sm)	Sm/Sp
1978	675	20,493	30.4	1979	3,812	52,900	13.9	2007	1,622	73,232	45.1
1979	2,249	41,056	18.3	1980	2,650	42,600	16.1	2008	58	3,257	56.2
1980	1,308	25,217	19.3	1981	2,234	99,800	44.7	2009	75	353	4.7
1981	922	23,620	25.6	1982	2,456	60,600	24.7	2010	913	63,135	69.2
1982	1,047	36,564	34.9	1983	538	48,200	89.6	2011	344	9,283	27.0
1983	745	26,062	35.0	1984	3,684	90,800	24.6	2012	186	6,734	36.2
1984	1,948	23,994	12.3	1985	1,563	47,500	30.4	2013	2,631	8,758	3.3
1985	589	11,510	19.5	1986	1,556	73,600	47.3	2014	383	3,372	8.8
1986	2,085	26,534	12.7	1987	1,784	86,000	48.2	2015	188	NA	
1987	1,028	17,594	17.1	1988	3,758	67,800	18.0	2016	226	14,628	64.7
1988	675	19,740	29.2	1989	1,408	52,600	37.4	2017	364	15,707	43.2
1989	850	23,646	27.8	1990	3,472	77,500	22.3				
1990	395	18,677	47.3	1991	1,610	63,100	39.2				
1991	579	13,071	22.6	1992	2,972	49,942	16.8				
1992	1,101	18,431	16.7	1993	3,462	43,900	12.7				
1993	1,339	16,574	12.4	1994	513	34,931	68.1				
1994	2,276	25,820	11.3	1995	2,033	81,516	40.1				
1995	1,795	40,828	22.7	1996	5,140	47,807	9.3				
1996	1,478	22,222	15.0	1997	636	28,750	45.2				
1997	2,994	20,967	7.0	1998	2,188	93,837	42.9				
1998	3,570	47,087	13.2	1999	2,787	101,328	36.4				
1999	628	21,803	34.7	2000	2,941	83,312	28.3				
2000	895	24,352	27.2	2001	10,556	74,415	7.0				
2001	3,318	36,060	10.9	2002	4,465	80,883	18.1				
2002	1,789	25,060	14.0	2003	3,791	76,249	20.1				
2003	4,647	32,949	7.1	2004	3,409	52,060	15.3				
2004	3,973	38,579	9.7	2005	2,984	60,250	20.2				
2005	1,082	29,911	27.6	2006	1,252	55,604	44.4				

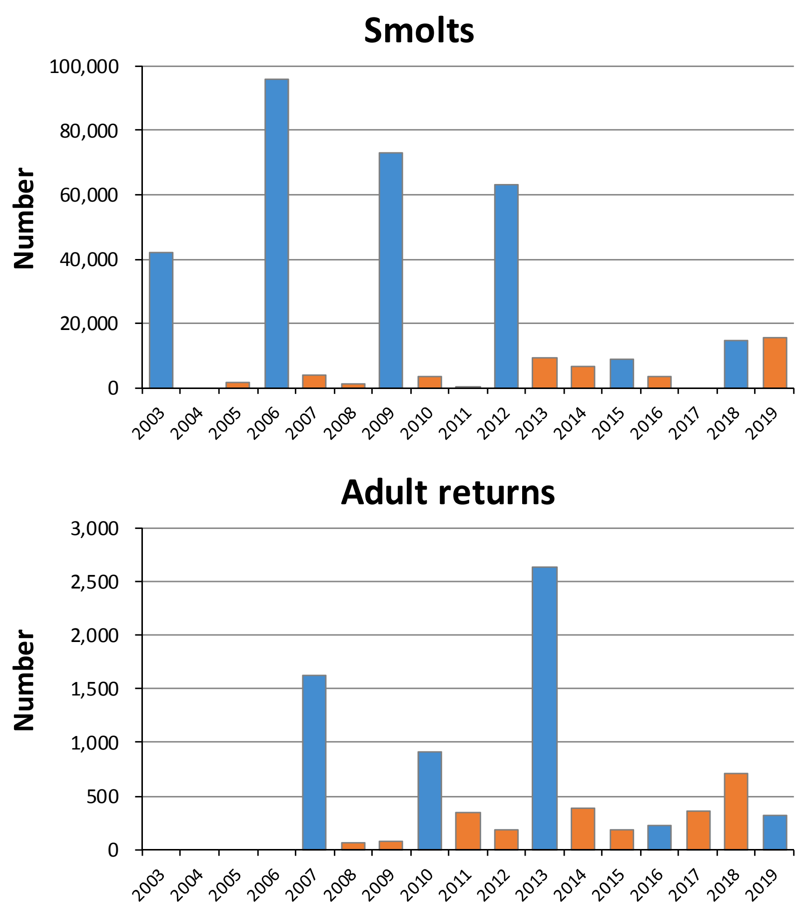

Figure 3-5. Smolt yield and adult returns in the Scott River subbasin to illustrate differences in brood line strength of the coho salmon population. Note that smolts in 2006 produced adult returns in 2007, smolts in 2009 produced adults in 2010, and so on. Blue bars depict numbers associated with the strong brood year lineage (beginning with smolts in 2003, produced from brood year 2001). Orange bars depict numbers associated with what has been considered to be weak brood line lineages.

Spawning ground surveys were initiated in 2001 in selected areas of the subbasin to assess coho salmon redd abundance and distribution. The surveys have been done mainly through the efforts of the Siskiyou Resource Conservation District (SRCD) and funded over time by the USFS and/or CDFW. Not all years since 2001 have been funded and data gaps exist. The surveys are only conducted on reaches where access is granted by property owners. Major gaps exist in the survey coverage of where coho potentially spawn. For available reports, see https://www.siskiyourcd.com/resources.

The presumed current distribution of coho salmon within the Scott River subbasin is shown in Figure 3-6 (as shown in ESA 2009). The historical distribution would very likely have been much greater due to the increased amounts of flow and connectivity of streams that existed prior to watershed alteration, as well as higher quality habitats that could have sustained the more expansive distribution.

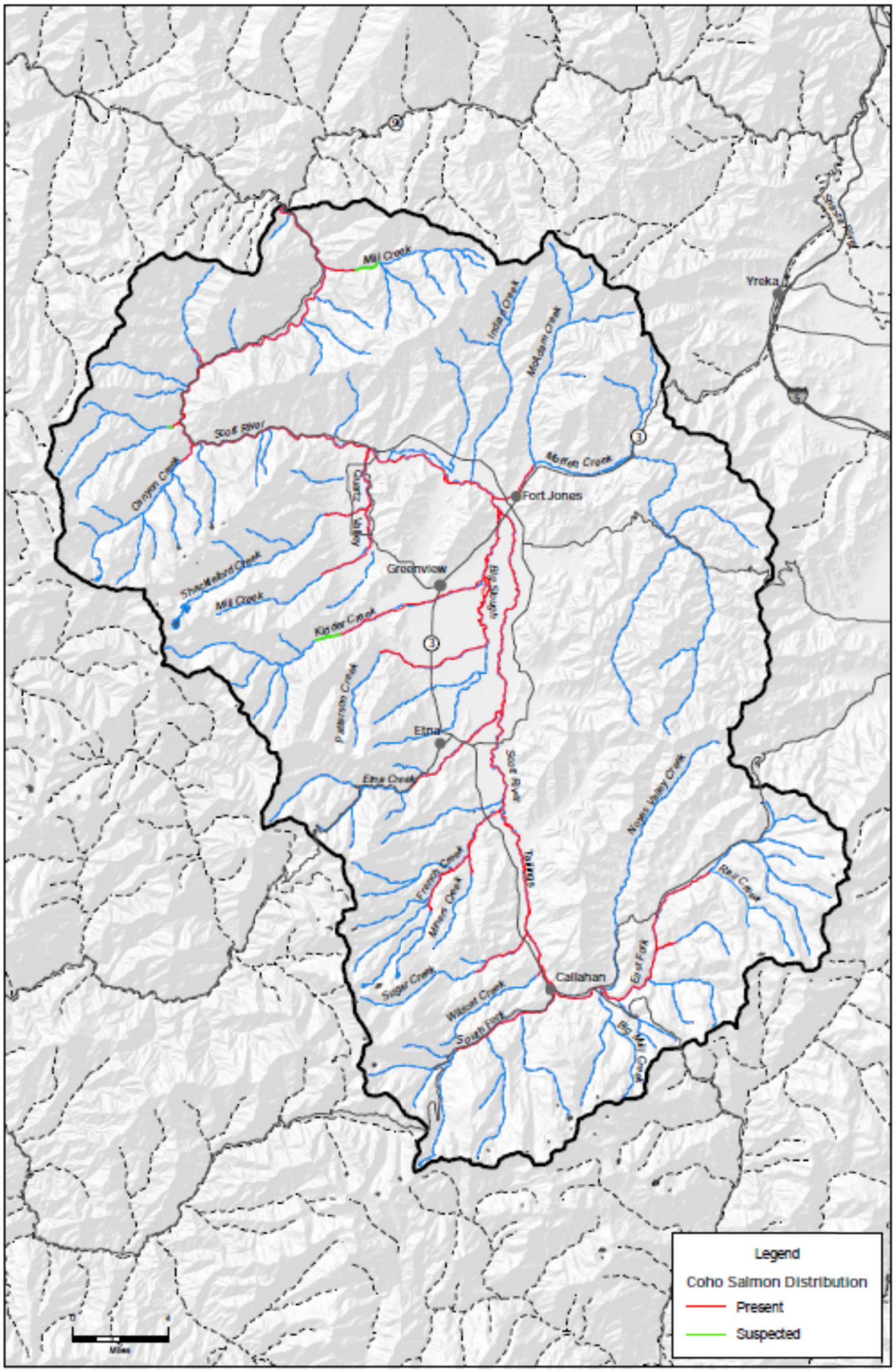

Figure 3-6. Coho distribution – from ESA (2009).

The large majority of coho salmon in the Klamath basin have a typical 3-yr life cycle common to the Pacific Northwest and California (Moyle 2002). The main exception to the 3-yr rule is jack males, which are 2 years old; jacks are sometimes observed at the Scott River video weir (e.g., Knechtle and Giudice 2018). Smolts are typically approximately 16 to 18 months old (age-1) at the time of their seaward migration. The majority of juvenile coho are believed to smolt from the Scott River subbasin, though it is known that some age-0 fish move out of the subbasin and oversummer and/or overwinter within the Klamath River mainstem corridor downstream of the Scott River (Soto et al. 2016). It is likely that the proportion of age-0 fish that emigrate out of the Scott River subbasin and overwinter downstream within the mainstem Klamath River corridor has increased over time as a result of habitat deterioration within the Scott Valley (Lestelle 2009; Soto et al. 2016). The Lestelle (2009) study is from the Olympic Coast in Washington where a long-term data set demonstrates such a pattern; it is reasonable to believe a similar pattern has occurred in the Scott River subbasin for the same reasons. Life stage periodicity (seasonal timing) for Scott River coho salmon is displayed in Figure 3-7.

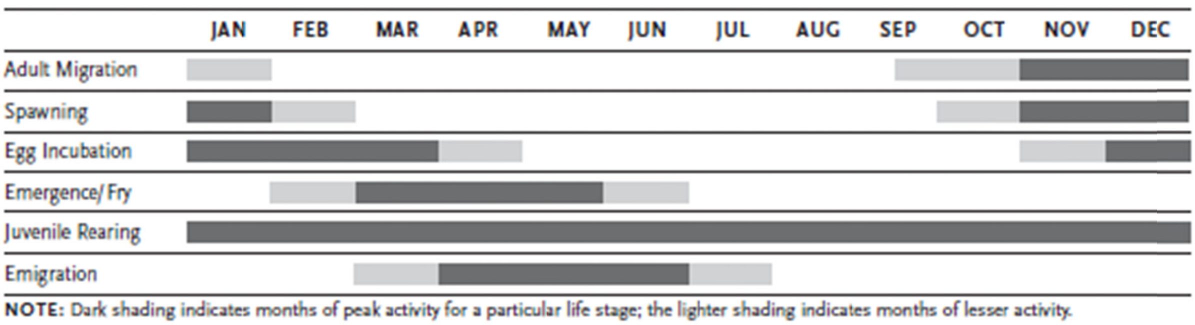

Figure 3-7. Generalized life stage periodicity (seasonal timing) of coho salmon life stages in California coastal watersheds, including Scott River. Taken from CDFG (2004).

Using an adaptation of the intrinsic potential (IP) method described in Burnett et al. (2003) and Agrawal et al. (2005), Williams et al. (2008) estimated the minimum number of coho spawners needed to maintain population viability in the Scott River subbasin to be 8,800 adults with a low extinction risk. The intrinsic potential (IP) method is a GIS-based approach for assessing potential salmonid production using modeled estimates of gradient, valley width, and average annual discharge. The authors implied that the 8,800 spawner level, which was believed to be less than the average historic adult run, would approach the number of spawners needed to seed the available historical habitat to its capacity.

I would note that this 8,800 figure, having been based solely on the IP method, does not incorporate population dynamics and all of the aspects of the VSP metrics.

NMFS concluded in its recovery plan for the SONCC ESU of coho salmon that the Scott River population was at moderate risk of extinction (NMFS 2014). NMFS also determined that a spawning escapement of at least 6,500 spawners needs to be achieved to maintain connectivity and diversity within the Interior Klamath River diversity stratum and continue to represent critical components of the evolutionary legacy of the ESU.

In its recovery plan for SONCC coho salmon, NMFS (2014) ranked the severity of different stresses to Scott River coho population. Stresses are the physical, biological, or chemical conditions and associated ecological processes that impede population recovery. These are the factors that the fish experience, such as disease, limited habitat access, insufficient instream flows, impaired water quality, and insufficient amount and quality of habitat. NMFS concluded that the two most significant stresses on this population within the subbasin are degraded riparian habitat conditions and the altered hydrologic function. The list of stresses and their ranking is shown in Table 3.6.

Table 3-6. Severity of stresses affecting each life stage of coho salmon in the Scott River. Taken from NMFS (2014).

	Stresses	Egg	Fry	Juvenile[1]	Smolt	Adult	Overall Stress Rank
1	Altered Hydrologic Function[1]	High	Very High	Very High[1]	Very High	Medium	Very High
2	Degraded Riparian Forest Conditions[1]	-	Very High	Very High[1]	Very High	Medium	Very High
3	Impaired Water Quality	Very High	High	High	High	Very High	Very High
4	Impaired Estuary/Mainstem Function	-	Low	High	High	Low	High
5	Lack of Floodplain and Channel Structure	Medium	High	Very High	High	High	Very High
6	Altered Sediment Supply	Very High	Very High	Medium	Medium	High	Very High
7	Adverse Hatchery-Related Effects	Medium	Medium	Medium	Medium	Medium	Medium
8	Increased Disease/Predation/Competition	Low	Medium	High	High	Medium	High
9	Barriers	-	Low	High	Low	Low	Low
10	Adverse Fishery- and Collection-Related Effects	-	-	Low	Low	Medium	Low

[1] Key limiting stresses and limited life stage.

The stress listed in Table 3-6 as "Increased Disease/Predation/Competition" needs special mention here. In particular, it is important to recognize that Scott River coho salmon are susceptible to Ceratomyxosis, the disease caused by the myxosporean parasite *Ceratonova shasta* (*C. shasta*), which is a source of mortality to salmonids, including coho salmon, in the mainstem Klamath River (Fujiwara et al. 2011). The parasite is endemic to the Klamath basin but streamflow regulation associated with flow management that occurs in the upper Klamath basin, combined with other factors in the river, has apparently increased its abundance and its effects on both wild and hatchery salmon in the river (Bartholomew and Foott 2010).

The prevalence of the parasite is highest between Iron Gate Dam (RM 190) and Scott River (RM 143), then generally decreases downstream, though it can still be substantial (Bartholomew and Foott 2010; Foott et al. 2011). High interannual variability can occur. Mortality to juvenile coho and Chinook salmon emigrating from the Klamath River can be very high (sometimes >50%). The amount of time of exposure by migrating juvenile salmon to the parasite is one of the key factors that can affect mortality (Foott et al. 2011). It is reasonable to assume that exposure of coho smolts emigrating from Scott River to the parasite is likely much lower than for Scott River juvenile Chinook, which likely move much more slowly seaward than coho smolts—and therefore mortality is likely lower for coho.

3.2.2. Fall Chinook Salmon

The Scott River historically produced both spring and fall-run Chinook (Moyle 2002; Moyle et al. 2008). Chinook salmon are classified as spring-run or fall-run depending on timing of river entry and spawning.

Recent research indicates these differences have a genetic basis (Prince et al. 2017; Thompson et al. 2019).

Chinook salmon in the Scott River subbasin are part of the federally-designated Upper Klamath and Trinity Rivers Chinook ESU, which includes all populations upstream of the confluence of the Klamath and Trinity rivers. NMFS determined in 1998 that this ESU did not warrant listing under the federal ESA.

The Scott River remains relatively productive for fall Chinook, though there can be little doubt that production has declined markedly from historical levels. No estimates of escapement are available prior to the 1950s (ESA 2009). In the early 1960s, fall Chinook runs returning to the Scott River were estimated to be 8,000-10,000 (SRWC 2005, as cited in ESA 2009), though it is uncertain how these estimates were made. Estimates of fall Chinook abundance returning to the Scott River have been made annually since 1978 and are regularly published in CDFW reports (e.g., Knechtle and Guidice 2019) and at the PFMC website (https://www.pcouncil.org/safe-documents-3/).

Table 3-7 lists estimated adult returns of fall Chinook to the Scott River subbasin for years 1978-2019 together with estimated spawning escapements of adult fall Chinook to the Klamath River system upstream of Trinity River. The average adult return over these years to the Scott River was approximately 4,100 fish, which was 16.9% of the total spawning escapement of naturally spawning adult fall Chinook in the Klamath basin upstream of the Trinity River (Table 3-7). To calculate this percent contribution of Scott River fish, I excluded the Trinity River because of the very large number of hatchery fish that spawn naturally in that system and areas downstream of Trinity River because fish that spawn there are considered to be a different ESU.

Table 3-7. Estimated spawning escapements of natural spawning fall Chinook salmon in the Klamath River and tributaries upstream of the Trinity River and returning to the Scott River subbasin, 1978-2019. Data are from the PFMC website (https://www.pcouncil.org/safe-documents-3/).

Year	Klamath R	Scott R	% Scott R
1978	27,440	3,423	12.5%
1979	22,609	3,396	15.0%
1980	13,783	2,032	14.7%
1981	18,517	3,147	17.0%
1982	22,677	5,826	25.7%
1983	13,500	3,398	25.2%
1984	10,410	1,443	13.9%
1985	16,460	3,051	18.5%
1986	20,812	3,176	15.3%
1987	29,797	7,769	26.1%
1988	34,770	4,727	13.6%
1989	14,423	3,000	20.8%
1990	7,914	1,379	17.4%
1991	6,782	2,019	29.8%
1992	4,889	1,873	38.3%
1993	15,953	5,035	31.6%
1994	21,427	2,358	11.0%
1995	83,918	11,198	13.3%
1996	38,680	11,952	30.9%
1997	34,637	8,284	23.9%
1998	18,028	3,061	17.0%
1999	11,660	3,021	25.9%
2000	58,388	5,729	9.8%
2001	40,944	5,398	13.2%
2002	54,225	4,261	7.9%
2003	55,423	11,988	21.6%
2004	10,711	445	4.2%
2005	13,554	698	5.1%
2006	14,264	3,007	21.1%
2007	21,292	4,494	21.1%
2008	19,020	3,445	18.1%
2009	27,743	2,167	7.8%
2010	15,170	2,114	13.9%
2011	17,973	3,019	16.8%
2012	72,786	7,569	10.4%
2013	31,711	4,036	12.7%
2014	70,709	10,419	14.7%
2015	23,273	2,092	9.0%
2016	10,376	1,376	13.3%
2017	13,832	2,269	16.4%
2018	37,505	1,208	3.2%
2019	13,534	1,681	12.4%
Average	26,465	4,095	16.9%

It is important to recognize that the percentage contribution of Scott River fall Chinook to the total aggregate population of fall Chinook that spawn naturally upstream of Trinity River is apparently declining over time. Table 3-8 summarizes average spawning escapements of naturally spawning adult fall Chinook in six-year time intervals beginning with 1978. From 1978 to 2001, approximately 17-19% on average of the total aggregate spawning escapement upstream of Trinity River was comprised of Scott River fish. Since 2001, the average percentage contribution has steadily declined. From 2014 to 2019, the average contribution was only 11%. Figure 3-8 displays the pattern of percentage contribution from 1978 to 2019. The pattern suggests that the performance of these fish over this time period is declining relative to the performance of non-Scott River fall Chinook within the ESU.[6]

Table 3-8. Estimated naturally spawning adult fall Chinook that returned to the Klamath River basin upstream of Trinity River averaged in six year intervals, 1978-2019.

Years	Klamath R	Scott R	% Scott R
1978-1983	19,754	3,537	18%
1984-1989	21,112	3,861	18%
1990-1995	23,481	3,977	17%
1996-2001	33,723	6,241	19%
2002-2007	28,245	4,149	15%
2008-2013	30,734	3,725	12%
2014-2019	28,205	3,174	11%

[6] / Kevin Malone, a consulting fish biologist, who peer reviewed an earlier draft of this report for the USFWS, suggested that the pattern of percentage contribution from the Scott River be examined in a couple of different ways. He pointed out that operations at Iron Gate Hatchery have changed over time. Prior to about 1996 when the hatchery was meeting broodstock needs, the ladder to the hatchery was closed after broodstock was met. As a result large numbers of hatchery fish would spawn in the mainstem river in the vicinity of the hatchery and in adjacent Bogus Creek. The number of natural-area spawners, therefore, outside of the Scott River was likely inflated compared to the number of just natural-origin spawners as a result of hatchery fish contributions. He suggested examining the pattern in two additional ways: (1) excluding Bogus Creek spawners from the analysis and (2) just using data beginning in 1996. Excluding Bogus Creek and just using data starting with 1996 shows a much tighter, declining trend for the percentage of spawners contributed by Scott River.

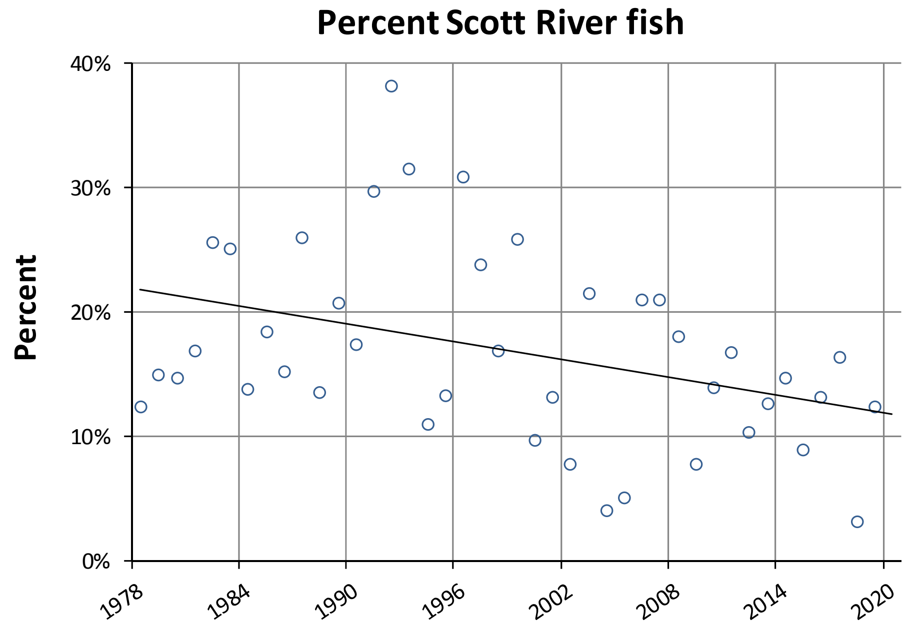

Figure 3-8. Percent of naturally spawning adult fall Chinook spawners in the Klamath River basin upstream of Trinity River, 1978-2019.

Scott River fall Chinook, like other Klamath River fall Chinook generally spawn during October to December. Spawning peaks during November in most Klamath basin tributaries before tapering off in December (Moyle et al. 2008).

Klamath River fall Chinook have a classic “ocean-type” juvenile life history, meaning the fry emerge from the gravel and begin a fairly rapid and continuous downstream emigration to the ocean as age-0 juveniles (Healey 1991; Moyle et al. 2008). Fry emergence generally occurs during February to April. Emigration timing and rate of movement by juveniles is highly variable and is dependent on river rearing conditions, which are controlled by both flow and water temperature. High winter flows, snowpack and subsequent spring runoff, summer weather conditions and smoke from forest fires (which can cool the water) all contribute to the annual variability in timing and duration of Chinook emigration (Moyle et al. 2008). Juveniles arrive at the estuary from April through August and ocean entrance is generally complete by the end of September (Wallace 2004; Moyle et al. 2008).

In the ocean, Klamath River fall Chinook largely remain off the coast between northern Oregon and Point Sur, California (south of San Francisco). Fishery impacts occur primarily closer to the Klamath River over this range (PFMC 2019).

The maturing adult Chinook return to the Klamath River generally in August and September and begin moving upstream to Scott River. Entry into the Scott River usually begins in early September, peaks in mid-October, and ends in early December (Hardy and Shaw 2015). Upon entering Scott River, their movement upstream is strongly affected by the amount of flow in the river.

When flow levels in the river are particularly low, the adult fall Chinook that enter into Scott River may delay their ascent upriver, becoming concentrated in the lower canyon by both holding in pools and, if delayed long enough, subsequently spawn within the canyon (Hardy and Shaw 2015). In extremely low flow years—and when fall rains are delayed—most, if not all of the adult fish attempting to move into the valley are prevented from doing so. This happens for two reasons. The first is that it is difficult for the large-bodied fish to negotiate the low flow conditions within the canyon. The second reason is that as flows drop to less than about 20 cfs at the USGS station there is an increasing likelihood that the river will be dry or nearly so a short distance upstream from the canyon in the lower end of the valley. Since 2015 (six years counting 2020), adult Chinook have been unable, or nearly so, to penetrate into the valley in the mainstem river in three years (2015, 2018, and 2020)—or 50% of the years. Figure 3-9 shows an adult fall Chinook attempting to move upstream in the canyon during a low flow year (picture taken in 2015).

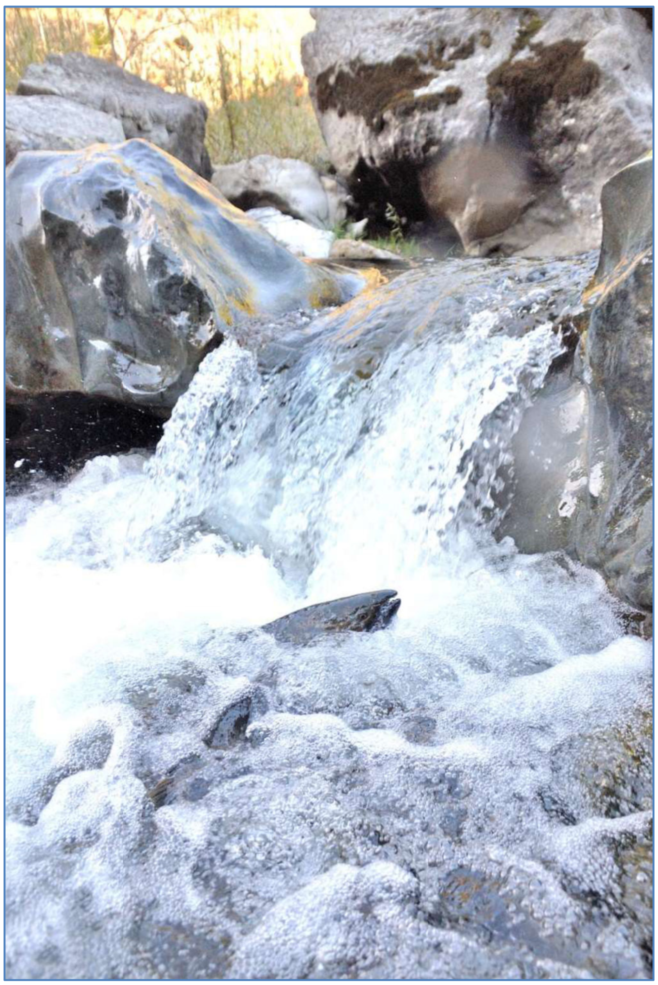

Figure 3-9. Low flow barrier to upstream migrating fall Chinook salmon in the Scott River canyon November 20, 2015. Picture from the cover of CDFW (2017). Average streamflow at the USGS gauging station near the top of the canyon on the day of this picture was 7.4 cfs.

Hardy and Shaw (2015) noted that the canyon reach is a higher gradient, confined channel, with narrow valley walls. Overbank flows have a limited floodplain resulting in increased depths and velocities in the active channel where Chinook spawn. During peak flow events there is a much higher redd scour potential, in comparison with reaches within the valley, where stream reaches have low gradient, less confinement, higher sinuosity, and a larger floodplain. Findings of Montgomery et al. (1996, 1999) indicate that fall and winter spawning salmonids are not likely to spawn in canyon reaches if given a choice because of the higher probability of redd scour occurring there as a result of winter freshets. My own observations made over a period of 20 years of spawning surveys on the Washington coast are consistent with those findings.

When flow conditions provide unrestricted passage, adult movement through the video weir location (near the top end of canyon) begins in late-September, peaks during the last three weeks of October, and concludes by late-November. Clayton (2006), cited in Hardy and Shaw (2015), reported that in early November 2005 discharge at Fort Jones peaked at 488 cfs, giving fall Chinook access to spawning areas throughout the valley reaches, Shackleford Creek, and into the East and South Forks of the Scott River.

It is uncertain what the historical spawning distribution was of fall Chinook in the Scott River subbasin. As noted above, when sufficient flows occur for unrestricted movement by adult fish, they move into the lower reaches of the East and South Forks and into the lower reaches of the larger tributaries. It is not known whether the presence of spring Chinook spawning prior to their extirpation in the subbasin has affected the distribution of fall Chinook salmon. It is reasonable to assume, however, that there was some spatial overlap in spawning between spring and fall Chinook since the upper part of the valley and the East and South Forks did not have flow barriers to separate the run-types. Genetic differences would have been largely maintained by temporal differences in spawning in the areas of spatial overlap, as occurs in rivers on the Washington North Coast.[7]

Klamath River fall Chinook are primarily 3 and 4 years old at spawning, though small percentages also return as age-2 jacks (precocious males) and age-5 fish. Sullivan (1989) concluded from sampling in one year (1986) at several of the counting weirs in the basin that over 50% of the return in that year was age-3. However, he also noted that age-4 fish may have been affected by El Nino conditions affecting ocean survival of brood year 1982 returns. PFMC (2019) described the age structure as follows:

> *"In August-September following the year of ocean entry, a small proportion of each cohort, mostly males (jacks), returns to the river to spawn as age-2 fish. The first major contribution to adult spawning escapement takes place during August-September after the second year of ocean entry, as age-3 fish. The majority of the adult fish in each cohort are destined to spawn by age-4, although the actual number of fish that survive to spawn may be less than the age-3 return due to variation in ocean and river survival rates. The very few remaining fish of each cohort mature at age-5 or very rarely at age-6."*

Snyder (1931) presented age data from gillnet catch data collected in the lower Klamath River in 1919, 1920, and 1923. In addition, Sullivan (1989) obtained scales collected from J.O. Snyder in 1921 and processed the samples to compare to the samples he took at the counting weirs for return year 1986.

---

[7] / This conclusion is based on years of observations I have made on the Washington North Coast and through discussions with Dr. Michael Miller at University of California – Davis.

He concluded that the dominant age class in the early 1920s was age-4 fish. Overall, he concluded that Klamath River fall Chinook were returning at a younger average age than fish that returned in the 1920s. This conclusion is consistent with the findings of Ricker (1981). In general, the decline in age and associated size is believed to be due to effects of fisheries, primarily in the ocean.

As noted earlier for coho, Scott River fall Chinook juveniles are exposed to *C. shasta* during their seaward emigration down the mainstem Klamath River. The effects of *C. shasta* on Klamath fall Chinook have likely increased over time as a result of a higher abundance of the parasite due to flow management that occurs in the upper Klamath basin, combined with other factors that have been changed in the river (Bartholomew and Foott 2010).

The prevalence of the parasite is highest between Iron Gate Dam (RM 190) and Scott River (RM 143), then generally decreases downstream, though it can still be substantial (Bartholomew and Foott 2010; Foott et al. 2011). High interannual variability can occur. Mortality to juvenile coho and Chinook salmon emigrating from the Klamath River can be very high (sometimes >50%), depending on a variety of factors, including amount of exposure in the mainstem Klamath River, water temperature, and other environmental factors which vary annually. It is reasonable to assume that exposure of fall Chinook juveniles emigrating from Scott River to the parasite is likely much higher than for Scott River coho smolts, due to a slower migration seaward of Chinook juveniles—and therefore mortality is likely higher for Chinook.

3.2.3. Spring Chinook Salmon

The Scott River historically produced both spring and fall-run Chinook (Moyle 2002; Moyle et al. 2008). Chinook salmon are classified as spring-run or fall-run depending on timing of river entry and spawning. Recent research indicates these differences have a genetic basis (Prince et al. 2017; Thompson et al. 2019).

Spring Chinook are believed to have been extirpated in the Scott River in the early 1970s due to a variety of causes (Moyle 2002). CDFG (1990, as cited in Moyle 2002) estimated the historical spring Chinook run to the Scott River as being at least 5,000 fish and gave the same approximate production level for three other Klamath basin tributaries: the Sprague River, Williamson River, and Shasta River. The basis of the 5,000 number was not given. It is known that spring Chinook were in steep decline by the 1930s (Snyder 1931), which leads me to conclude that the number was essentially an educated guess. He attributed the number to CDFG (1990). Moyle gave no rationale for the 5,000 fish number. I note that CDFG (1990) does not mention any estimated abundance for the Scott River so the source and rationale for the 5,000 fish number are unknown.

The historical spawning distribution of spring Chinook in the Scott River is not known but it can be assumed that these fish ascended as high into the subbasin as possible due to cooler water located there. It is reasonable to assume that there was some spatial overlap in spawning between spring and fall Chinook since the upper part of the valley and the East and South Forks did not have flow barriers to separate the run-types. Genetic differences would have been largely maintained by temporal differences in spawning in the areas of spatial overlap, as occurs in rivers on the Washington North Coast.

4. Historical and Current Baselines

Two reference baselines were developed by modeling: one intended to represent the historical pre-contact period, i.e., before watershed alterations beginning in the mid-19th century, and the other to represent the current period. These are called the historical and current baselines—or scenarios. Both baselines describe reference salmon performance levels used to diagnose the condition of the Scott River subbasin for supporting salmon populations. The two reference baselines also provide a basis for assessing potential benefits of different restoration scenarios.

It bears noting that the current period is meant to represent a more or less average set of conditions that might prevail over a roughly ten year period given the normal range of environmental variability that could be expected over that time. Regarding the prevailing weather patterns over such a period, an average set of flow years is assumed—neither a period of continuous drought nor one of continuous wet years. Some variability that would encompass both dry and wet years is assumed.

4.1. Methods for Baseline Analysis

This section describes the methods used for defining the stream network used in the EDT model, the characterization of the environmental attributes that define habitat conditions, and the characteristics of the salmon populations applied by the model.

4.1.1. Stream Reach Delineation

Stream reaches for use in the model extend from the upper parts of the Scott River subbasin to the Klamath River mouth, including the estuarine reach of the river. The relevant stream network was identified based primarily on the 1:100,000 National Hydrography Dataset (NHD) hydrography supplemented with the 1:24,000 NHD hydrography as developed by the U.S. Geological Survey.

Stream reaches within the Scott River subbasin were delineated based on how they are differentiated with regard to tributary locations, major geomorphic breaks, differences in hydrologic patterns, irrigation withdrawals, major road crossings, and other obvious features that occur along the stream courses with respect to physical and water quality characteristics. Reaches were delineated up to approximately 8-10 % channel slope within each stream course where one or more salmonid species, including steelhead, are known to occur or where presumed likely to have occurred historically.

A total of 268 stream reaches with lengths >0 ft were delineated within the Scott River subbasin. In addition, another 68 reaches with assumed lengths of 0 ft were identified as being associated with specific locations where water withdrawals or culvert crossings occur – sites where fish passage might be impeded or direct mortality might occur. In actuality these 0 ft length reaches have lengths somewhat greater but only by relatively few feet. The assumption of lengths of 0 ft has no effect on fish performance in the model. Combined, a total of 336 reaches were delineated within the subbasin to be used in modeling. The total length of these reaches under current baseline conditions was estimated to be 247 mi.

The mainstem Klamath River downstream of the confluence with Scott River was also delineated by stream reaches to enable the model to analyze the full life cycle of each salmon population. The Scott River joins the Klamath River at RM 143. Including the estuarine reach, the mainstem Klamath River was partitioned into four reaches:

1. Scott River to Salmon River;
2. Salmon River to Trinity River;
3. Trinity River to top end of estuary; and
4. Klamath River estuary.

In the model, the ocean environment is a separate geographic unit—in effect its own reach, thus closing the life cycle over a population's entire environment experienced from egg deposition back to spawning.

Reach lengths and channel gradients were determined through use of GIS analysis, topographic maps (Terrain Navigator Pro), and aerial photographs. Appendices D and E list all stream reaches that were delineated within the Scott River subbasin. Reaches are ordered in the appendix tables starting at the confluence with the Klamath River using the U.S. Environmental Protection Agency's (EPA) system of ordering stream reaches to show how they connect within the stream system. (Moving upstream from the river mouth, each reach is sequenced until the first tributary is reached, and then reaches are shown sequentially up that stream until a tributary is reached, and so on. When the top of a tributary is reached, the next reach along the main stream upstream of the tributary is shown next and so on to the top end of the entire subbasin. The table thus provides a tabular map that one can use to identify where each reach is located.)

While the modeling analysis is performed across all reaches assumed to be used by any life stage for a species, the spatial scale of the modeling outputs are produced using what are referred to as Diagnostic Units (or simply termed Geographic Areas in output presented herein), which are combinations of stream reaches aggregated in a manner deemed to be more useful than at the reach scale. The delineation of these Geographic Areas applied in the diagnostic steps with the model is described in Section 5.1.2 (see Table 5-1 for definitions of Geographic Areas).

4.1.2. Characterizing Attributes of Primary Importance

EDT uses over 45 different environmental attributes to characterize conditions of all stream reaches. The attributes describe stream reach size (channel wetted width and length), channel slope, temperature, flow, sediment, riparian conditions, wood load, habitat types, and other environmental conditions of importance to salmon survival. While the full set of attributes is large and diverse, typically only a relatively small subset of these is relevant within a certain environmental setting. The full set of attributes enables the model to evaluate a broad range of stream types and environmental settings, from historical conditions largely unaltered by man to urban streams that are highly modified. The attributes are characterized for the model using a standard nomenclature for all stream reaches and across all 12 months of a year. Attribute definitions for all attributes used in the model are given in Appendix B.

The attributes found to be most important in the Scott River subbasin to salmon performance are listed and defined in Table 4-1.

Table 4-1. List of attributes of primary importance in the Scott River subbasin. See Appendix A for complete list of all attributes modeled. Definitions shown here may be shortened from those given in the appendix.

Attribute	Definition
Channel length	Length of the primary channel contained with the stream reach.
Confinement - natural	The extent that the valley floodplain of the reach is confined by natural features. Attribute addresses the natural (pristine) state of valley confinement only.
Confinement – Hydromodifications (or Confinement artificial)	The extent that man-made structures within or adjacent to the stream channel constrict flow or restrict flow access to the stream's floodplain (due to streamside roads, revetments, diking or levees) or the extent that the channel has been ditched or channelized, or has undergone significant streambed degradation due to channel incision/entrenchment.
Embeddedness	The extent that larger cobbles or gravel are surrounded by or covered by fine sediment, such as sands, silts, and clays.
Flow - changes in interannual variability in low flows	The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime (or as would have existed in the pristine state). Note: low flows are not systematically reduced in relation to watershed development, even in urban streams (Konrad 2000). Factors affecting low flow are often not obvious in many watersheds, except in clear cases of flow diversion and regulation.
Fine sediment	Percentage of fine sediment within salmonid spawning substrates, located in pool-tailouts, glides, and small cobble-gravel riffles.
Gradient	Average gradient of the main channel of the reach over its entire length.
Reach habitat types (%)	The percentage of the wetted channel surface area comprising pools, backwater pools, beaver ponds, glides, small cobble/gravel riffles, and large cobble riffles.
Habitat type – side channel	The mean monthly proportion of the wetted area of all in-channel habitat (main channel, side channels and braids) consisting of side channels.
Obstructions to fish migration	Obstructions to fish passage by physical barriers (not dewatered channels or hindrances to migration caused by pollutants or lack of oxygen).
Riparian function	A measure of riparian function that has been altered within the reach.
Temperature - daily maximum (month)	Maximum water temperatures within the stream reach during a month.
Wood	The amount of wood (large woody debris or LWD) within the reach.
Water withdrawals	The number and relative size of water withdrawals in the stream reach.
Channel Minimum width (ft) (month)	Average width of the wetted channel during the low flow month.

The primary sources of information used in characterizing the attributes are listed in Table 4-2. Other reports also provided information for some parts of the subbasin.

It bears noting that available information sources were applied directly in characterizing conditions of the current baseline scenario for the streams or sections of streams most relevant to the available information. Inferences and/or extrapolations were then made to other streams and parts of streams based on that information as is usually needed in EDT modeling (Blair et al. 2009).

Table 4-2. Primary sources of information used to characterize the stream environment of the Scott River subbasin as applied in the EDT model.

Environmental characteristics	Primary sources	Citations
Sediment load • Fine sediment concentrations in salmon spawning areas in misc. tributaries and Scott R. • Embeddedness values • Characterized for both historical and current conditions	Scott River Basin Granitic Sediment Study; Scott River Watershed Monitoring Program 2005, 2006 & 2007; Scott River Spawning Gravel Evaluation and Enhancement Plan	CDFG (2002a, 2002b, 2002c, 2002d, 2002e, 2002f, 2005, 2008a, 2008b); Sommarstrom et al. (1990); Quigley (2003, 2008); USFS (2000); Cramer Fish Sciences (2010)
Riparian conditions • Riparian condition for all relevant stream reaches in the subbasin • Characterized for both historical and current conditions	Scott River Basin Granitic Sediment Study; Lower Scott Ecosystem Analysis; Google Earth	Sommarstrom et al. (1990); USFS (2000)
Water diversions • Locations of diversions and amounts of water diverted (either at specific sites or approximate aggregated amounts at different locations)	Scott River Watershed CRMP Committee; Scott River Watershed-wide Permitting Program Final Environmental Impact Report FEIR Volume 1: Chapter 3.3; State Water Resources Control Board – maps showing diversions and irrigated lands; Scott River Water Trust reports	Davis (1997); ESA (2009); SWRCB (1979); Yokel (2008, 2009, 2012); Thamer (2013, 2015)
Wetted channel width and associated streamflow • Average wetted channel width and average daily flow during an average water year during winter and in late summer/early fall • Characterized for both historical and current conditions	Scott River Watershed CRMP Committee; Scott River Watershed-wide Permitting Program Final Environmental Impact Report FEIR Volume 1: Chapter 3.3; State Water Resources Control Board – maps showing diversions and irrigated lands; Scott River Water Trust reports	CDFG (2002a, 2002b, 2002c, 2002d, 2002e, 2002f, 2005, 2008a, 2008b); Davis (1997); ESA (2009); SWRCB (1979); Yokel (2008, 2009, 2012); Thamer (2013, 2015); Magranet (2016)
Streamflow at specific locations Prepumping conditions • Streamflow at summer low flow in specific years Current conditions: • Streamflow at summer low flow in specific years	Scott River USGS gauge at Fort Jones 11519500; East Fork USGS gauge 11518050; South Fork USGS gauge 11518200; Moffett Cr USGS gauge 11518600; Shackleford Cr USGS gauge 11519000; Sugar Cr USGS gauge 11518300; F25650 French Cr Hwy 3; CDFG habitat survey reports; Water Trust reports; Scott River Summer Habitat Utilization Study	USGS flow records; CDWR flow records (French Cr); CDFW (2017); CDFG (list years); Yokel (2006); Yokel (2008, 2009, 2012); Thamer (2013, 2015); Magranet (2016); CDFG (2002a, 2002b, 2002c, 2002d, 2002e, 2002f, 2005, 2008a, 2008b)
Water temperature Historical conditions • Inferences from other EDT data sets with similar watershed characteristics and climate Current conditions • Scott River subbasin water temperatures at various sites for 1992-2007 (MWAT values adjusted to MWMT values)	Scott River Watershed Water Quality Compliance and Trend Monitoring Plan (contains summarized data for large number of sites within the subbasin); Scott River Watershed-wide Permitting Program Final Environmental Impact Report FEIR Volume 1: Chapter 3.2; misc. data sets from USFS; inferences to historical conditions made using the Grande Ronde watershed in Northeast Oregon and the Chehalis River in Southeast Washington	ESA (2009); NCRWB (2011); USFS water temperature data sets; EDT data sets for Grande Ronde and Chehalis River watersheds
Channel pattern and floodplains Historical conditions:	Scott River Basin Granitic Sediment Study; Lower Scott Ecosystem Analysis;	Sommarstrom et al. (1990); USFS (2000); ESA (2009);

Environmental characteristics	Primary sources	Citations
• Inferences from Sommarstrom et al. (1990) and USFW (2000) Current conditions: • Channel patterns and connectivity to floodplains within the canyon, valley, and upper subbasin	Scott River Watershed-wide Permitting Program Final Environmental Impact Report FEIR Volume 1 Chapter 3.3; Google Earth imagery	Google Earth; Tim Abbe (Natural Systems Design, *personal communications*)
Channel form (incision, bank hardening) Historical conditions: • Inferences from Sommarstrom et al. (1990) and USFW (2000) Current conditions: • Channel patterns and connectivity to floodplains within the canyon, valley, and upper subbasin	Scott River Basin Granitic Sediment Study; Lower Scott Ecosystem Analysis; Scott River Watershed-wide Permitting Program Final Environmental Impact Report FEIR Volume 1 Chapter 3.3; Google Earth imagery	Sommarstrom et al. (1990); USFS (2000); ESA (2009); Google Earth; Tim Abbe (Natural Systems Design, *personal communications*)
Habitat types (meso-habitat type) • Average % composition of habitat types within the stream reaches (pools, beaver pools/ponds, riffles, backwater pools, off-channel habitats) • Characterized for both historical and current conditions	Sommarstrom et al. (1990); Google Earth imagery	CDFG (2002a, 2002b, 2002c, 2002d, 2002e, 2002f, 2005, 2008a, 2008b); Quigley 2003; Mount et al. 2003.
Wood • Average woody material load within the stream reaches • Characterized for both historical and current conditions		CDFG (2002a, 2002b, 2002c, 2002d, 2002e, 2002f, 2005, 2008a, 2008b); Quigley 2003; Mount et al. 2003.

To characterize the historical conditions prior to settlement by non-Indians, inferences were made based on descriptions of the subbasin prior to alterations given in Sommarstrom et al. (2000) and USFS (2000), inferences made from conditions described for current conditions (Table 4-3), and on field trips to the area with Tim Abbe (geomorphologist, Natural Systems Design) and Rocco Fiori (geologist, Fiori Geological Science). Discussions with Michael Pollock (geomorphologist, NMFS), who has done research for a number of years in some streams within the valley, also were helpful. I applied similar reasoning and procedures that I have used in developing historical reconstructions for many watersheds in the Pacific Northwest (e.g., Grand Ronde River watershed [Mobrand and Lestelle 1997], Puyallup River watershed [Mobrand Biometrics 2003b], Chehalis River watershed [Mobrand Biometrics 2003a], rivers of Hood Canal and the eastern Strait of Juan de Fuca [Lestelle et al. 2005a, Thompson et al. 2009], rivers of north central Oregon [Carmichael and Taylor 2009]). The characterization of the historical set of conditions represents a hypothesis about those conditions based on landform features, geology, climate, and expected vegetative cover and other biota (Lichatowich et al. 1995; Blair et al. 2009).

The characterizations of the historical and current baseline conditions are made with quantitative metrics (see Appendix C), which lend themselves to computing percent changes in the metrics between those two sets of conditions. Table 4.3 lists the percent changes in the attribute characterization metrics for important attributes identified in the Scott River subbasin for each of the Geographic Areas (Diagnostic Units).

Table 4-3. Percent changes in important environmental attributes in the Scott River subbasin between the historical and current baseline conditions within the Geographic Areas (or Diagnostic Units); abbreviations are Fine Sedi (fine sediment), Embed (embeddedness), Temp Mx (maximum daily temperatures), Riparian (riparian function), Wood (wood), Confine Art (artificial confinement), Multi Chan (side channels and channel form), % Pools (% scour pools), Wet width (wetted channel width at summer flow flow), Chan len (channel length).

Geographic area	Fine Sedi	Embed	Temp Mx	Riparian	Wood	Confine Art	Multi Chan	% Pools	Wet width	Chan len
SR canyon MS lower	28%	17%	0%	24%	90%	0%	0%	0%	50%	0%
SR canyon MS upper	25%	17%	3%	32%	90%	0%	0%	0%	56%	0%
SR valley to Kidder Cr	37%	17%	56%	90%	92%	67%	100%	46%	78%	23%
East tribs to Ft Jones	29%	17%	69%	92%	99%	83%	100%	64%	78%	4%
Sniktaw Cr	17%	17%	31%	57%	86%	42%	100%	40%	48%	8%
Shackleford Cr	39%	17%	38%	66%	79%	67%	100%	66%	68%	12%
Mill-Emigrant Cr	17%	17%	23%	62%	58%	50%	100%	33%	8%	10%
Oro Fino Cr	28%	17%	63%	100%	100%	100%	100%	100%	85%	17%
Moffett Cr lower	35%	17%	44%	92%	95%	100%	100%	61%	99%	3%
Moffett Cr upper	30%	17%	31%	75%	90%	34%	0%	56%	47%	0%
Kidder lower-Big Slough	54%	17%	66%	93%	93%	71%	100%	45%	54%	13%
Patterson Cr	31%	17%	27%	67%	89%	60%	100%	63%	35%	4%
Crystal-Johnson Cr	60%	25%	69%	100%	97%	100%	0%	63%	50%	0%
Kidder Cr upper	36%	17%	18%	74%	88%	47%	100%	45%	48%	7%
SR valley to Etna Cr	79%	33%	37%	96%	92%	75%	100%	47%	73%	23%
East Slough	75%	17%	75%	100%	100%	100%	100%	47%	0%	0%
Etna Cr	28%	28%	27%	53%	92%	51%	100%	66%	46%	6%
SR valley to tailings	44%	35%	29%	91%	80%	53%	37%	46%	70%	23%
Clark Cr	20%	20%	29%	68%	79%	69%	0%	56%	62%	7%
French Cr lower	45%	43%	28%	64%	56%	45%	100%	59%	61%	17%
Miners Cr	29%	27%	29%	40%	33%	25%	0%	41%	26%	0%
French Cr upper	14%	14%	27%	21%	40%	25%	0%	64%	35%	0%
Wolford Slough	43%	0%	50%	63%	76%	50%	100%	41%	0%	0%
SR valley to forks	24%	24%	31%	89%	78%	96%	100%	14%	63%	18%
Sugar Cr	22%	22%	12%	35%	39%	31%	100%	22%	23%	1%
Wildcat Cr	17%	17%	17%	64%	100%	64%	0%	39%	43%	9%
South Fork MS	14%	14%	13%	45%	73%	17%	100%	53%	28%	0%
South Fork tribs	14%	14%	1%	15%	67%	1%	100%	0%	9%	0%
East Fork MS lower	8%	8%	37%	63%	93%	62%	100%	44%	43%	0%
East Fork MS upper	10%	10%	13%	69%	93%	50%	0%	54%	30%	0%
East Fork tribs	29%	19%	17%	38%	83%	37%	0%	12%	40%	0%

The derivation of the wetted channel widths for all stream reaches was done by first estimating average daily streamflows (cfs) for each month and each baseline scenario, as well as for the prepumping (1970s) condition. Estimates of streamflow were then converted to estimated wetted channel widths using the default equations often applied in the EDT model given in Lestelle (2005). The procedure applied in estimating average daily streamflow involved a number of steps, outlined below:

- Flows in the mainstem Scott River were derived by first developing the longitudinal pattern of flows in late summer at reference sites along the river from empirical information available for various years measured at different sites, primarily from Yokel (2006, 2008, 2009, and 2012) and Thamer (2013 and 2015). The overall pattern was obtained by combining the data into patterns and drawing inferences from those patterns to each of the stream reaches along the river.
- For the current baseline condition (representing an average water year – not a severe drought year), the surface streamflow exiting the valley was assumed to be approximately 23 cfs during September (Table 3-1). The value of 23 cfs is the average daily flow in September for the period 2003-2017 (15 years), which includes a mix of water year types. Flows at other reference points along the mainstem river for September were then computed to be consistent with the spatial longitudinal pattern as described above.
- Measured flows at various reference sites within tributaries taken from various reports for late summer months for years during the 2003-2017 period (citations given in Table 4-2) were used as key sites for deriving reach-by-reach flows in a manner to be consistent with those measured flow observations. Flow diversion sites and amounts listed as being diverted (see sub-bullet immediately below) were then used to derive the reach-by-reach flows. These reach-by-reach flow amounts are the flow rates applied as the current baseline condition.
    - Amounts diverted by surface water diversions were taken from a variety of sources listed in Table 4-2; particularly useful for this step were the summaries of diverted amounts given in SWRCB (1979), Davis (1997), and ESA (2009). Adjudication notes and maps were also used in this step to inform specific sites. The reports by Yokel (2008, 2009, and 2012) and Thamer (2013, 2015) were also helpful in this step for specific sites.
- Reach-by-reach flow rates for the prepumping scenario for tributaries were assumed to be equal to those applied to the current condition baseline. For this scenario, the mainstem river flows were adjusted upward consistent with the longitudinal pattern described above so that the streamflow exiting the valley at the USGS gauge station equaled 62 cfs in September (Table 3-1).
- Historical streamflows were derived for September by turning all diversions off.
- The final step in estimating historical streamflows added an additional 20% to the amount calculated in the step immediately above to account for lost water storage in valley and floodplains upstream of the valley due to the almost complete loss of beaver complexes that occurred in the 1800s, combined with drainage of wetlands and incision. This amount is assumed and is an uncertainty, but is inferred from information contained in Pollock et al. (2003 and 2014).

- High flows during winter and spring were assumed to be unchanged from present levels.

Estimates of wetted channel widths and summer low flow for each reach for historical and current baselines are listed in Appendix E.

While this report focuses the analysis and discussion on environmental effects occurring within the Scott River subbasin, the modeling also included effects on population performance that occur within the mainstem Klamath River. As noted in Section 4.1.1, the mainstem Klamath River was delineated into three reaches upstream of the river-mouth estuary. These reaches were also characterized using the same EDT attributes described above for the Scott River subbasin. For the Scott River analysis, I used an EDT data set that was originally configured for the mainstem Klamath River in 2006 when some preliminary modeling was done for the Shasta River and the upper Klamath Basin.[8] I updated several attribute values in the mainstem river to account for differences between historical and current conditions that had not previously been incorporated. Most notably, I updated the attribute "Fish pathogens" to incorporate a reasonable assumption about differences in *C. shasta* abundance along the mainstem river, consistent with patterns described in Bartholomew and Foott (2010) and Foott et al. (2011). The older model configuration assumed that *C. shasta* abundance was the same from the Shasta River to the Klamath River mouth and was the same for both the historical and current conditions.[9]

4.1.3. Salmon Population Characteristics and Modeling

Habitat potential for each scenario was evaluated for three salmon populations in the Scott River subbasin: coho, fall Chinook, and spring Chinook salmon.

Certain basic species characteristics need to be described as inputs to the model for each population. These are:

- Spawning distribution;
- Life stage periodicity (or life stage timing);
- Average fecundity by age;
- Average age structure of the adult population; and
- Life history patterns.

The EDT model applies these characteristics to estimate habitat potential for each scenario being modeled.

4.1.3.1. Coho Salmon

The upper extent of spawning distribution of coho in each stream was defined based on stream gradient, stream size, and reported observations of spawning made on spawner or juvenile presence.

---

[8] / This earlier modeling was done by staff of Mobrand-Jones and Stokes, Inc., the company that owned the EDT model at that time. I was not involved in those modeling exercises.

[9] / The modelers doing this earlier work were interested in effects of environmental changes in specific areas of the basin and therefore elected to set attribute values in downstream mainstem areas to be equal between the historical and current condition scenarios. My interested, while focused on effects within the Scott River subbasin, aimed to incorporate the full suite of reasonable potential effects of environmental changes within the Klamath Basin on the Scott River populations.

Generally, the upper extent of coho spawning was allowed in the model to extend to approximately 4% gradient, though this varied some based on stream size. Spawning was allowed in the model in all stream reaches downstream of those upper limits, including within the mainstem Scott River. This distribution of spawners allowed in the model does not necessarily mean that spawning in all these locations would be successful at producing returning adults—whether spawning could be sustained at these sites would depend on the success of a full life cycle being initiated there. The same spawning distribution was allowed in each scenario being modeled.

The timing of coho life stages (periodicity) assumed for modeling is displayed in Figure 3-7. Life stage periodicity for Scott River coho was defined based on various information sources (e.g., Moyle 2002; Lestelle 2007; NMFS 2014). The periodicity of Scott River coho is assumed to be similar to that of coho elsewhere in northern California and western Oregon.

The fecundity of Scott River coho was assumed to average 2,500 eggs, which is generally consistent with fecundities observed elsewhere in northern California and western Oregon (Au 1971; Moyle 2002). California coho tend to have lower fecundities than more northern populations (Moyle 2002).

The sex ratio of the spawning population was assumed, on the average, to be comprised of a 1 to 1 ratio of females to males, which is consistent with what is commonly observed in the Pacific Northwest and California (Quinn 2018).

The population was modeled assuming that all spawners are 3-year old adults, though in reality some coho return as 2-year old precocious males or jacks (sometimes called grilse in California). Estimates of coho run sizes are normally reported only for adults—therefore, I made no attempt to model the return of 2-year old fish.

Juvenile coho in northern California streams can exhibit a range of movement patterns as age-0 fish, depending on habitat conditions encountered (Lestelle 2006; Hillemeier et al. 2009; Soto et al. 2016). These patterns can generally be grouped into three primary patterns seen in many coho populations in the Pacific Northwest and California, which have been incorporated into the modeling. The three patterns as modeled here are described briefly below:

- Age-0 resident rearing – All emergent fry generally stay close to where they were spawned though some relatively short relocations are allowed. The fish rear through the summer, and then overwinter in the general vicinity of their natal reach, before emigrating seaward as age-1 smolts.
- Age-0 migrant rearing – Emergent fry exhibit some downstream dispersal from where they were spawned—in this setup of the model the downstream dispersal was constrained to a maximum of 3 miles. Following this initial dispersal, rearing locations through the summer period were assumed to remain relatively unchanged during the summer rearing life stage. In fall (or early winter), a redistribution then occurs, representing fish that exhibit a substantial movement in search of more suitable habitat for overwintering, prior to emigrating seaward as age-1 smolts.

- Age-0 resident rearing with fall redistribution – This pattern joins the two patterns described above so that the juveniles remain in relatively close proximity to their natal sites before exhibiting a downstream redistribution in fall to find overwintering habitat.

Modeling juvenile coho life histories with any life cycle model, such as EDT, raises the question: How far do the juveniles travel during fry dispersal and as parr during the fall/early winter redistribution (the second and third patterns described above)? A related question is what proportions of the population exhibit these different life history patterns? EDT models a large set of specific life history pathways (trajectories) within each of the life history patterns, and then rolls up the performance results of the trajectories by weighting them by their relative performance to produce population level results (Blair et al. 2009). Both questions needed to be considered in configuring the model.

The question of how far coho fry and parr move during their redistributions within a river system has been investigated as part of the Klamath River Coho Ecology Study being conducted of the Karuk and Yurok tribes (Hillemeier et al. 2009; Soto et al. 2016). That study, aimed at understanding the role of the mainstem Klamath River corridor to the overall performance of Klamath River wild coho, has found very extensive movements of non-natal juvenile coho within the mainstem river corridor. Distances traveled can be particularly significant during the fall and early winter parr redistribution. For example, some fish travel as much as 200 miles downstream from natal locations to overwinter near the river's estuary. The study has also found that the mainstem Klamath River corridor contains a very limited number of high quality summer and/or overwintering habitats for juvenile coho, and the sites are generally very small in size with a very sporadic distribution along the river.

The EDT model was not configured to investigate the effect of different juvenile coho movement patterns within the mainstem Klamath River, which would have required a much more detailed characterization of Klamath River habitats and adjoining habitats within the corridor. It would have been necessary to have a much finer scale in reach delineation within the mainstem corridor also. The focus of the assessment made for this report was on understanding the effects of habitat conditions within the Scott River subbasin on its salmon populations—this necessarily also includes consideration of conditions within the mainstem Klamath River, but not at a scale that would have been needed if the focus was on modeling effects of restoration actions within the mainstem river corridor. Therefore, limits on distances moved by juvenile coho spawned within the Scott Valley and upstream areas were constrained so that age-0 fish remained upstream of the head of the Scott River canyon at RM 22. Juveniles produced from canyon spawners were allowed to move downstream out of the Scott River but not by a large distance.

The three life history patterns described above were modeled using 5,000 individual life history trajectories, each originating from a presumed spawning location. In effect, the use of a large number of specific trajectories in this manner serves to sample the habitat mosaic of the river system in a manner consistent with the three generalized life history patterns (Mobrand et al. 1997; Blair et al. 2009). Allocation of the 5,000 trajectories among the three life history patterns was then made simply to provide an equitable sampling of the life history possibilities between the resident rearing pattern and the migrant patterns. Therefore, 50% of the trajectories were prescribed to be within the resident pattern and 50% within the two migrant patterns combined.

In the model, the only segment of each life history trajectory in which survival was not determined expressly by habitat conditions encountered along the pathway is in the estuary and ocean. For this segment, the smolt to adult survival (often referred to as the smolt to adult recruitment rate or SAR) was assumed to be approximately 5%, based on an average SAR value derived from Knechtle and Giudice (2019).

4.1.3.2. Fall Chinook Salmon

The spawning distribution of Chinook salmon—both for fall Chinook and formerly for spring Chinook has not been clearly described for the subbasin. Uncertainties exist about these distributions. Historically, there was likely some amount of spatial overlap between the run-types. Population structure was likely maintained by separation in spawning timing, though some amount of interbreeding may have occurred between run-types (Thompson et al. 2019; Ford et al. 2020).

To model the fall Chinook population, spawner distribution was assumed to occur throughout the mainstem Scott River from its mouth to French Creek (RM 47.3). In actuality, variability in the upper extent of spawning presumably occurs from year to year depending on flow levels. Clayton (2006), cited in Hardy and Shaw (2015), noted that fall Chinook spawning has occurred into the lower reaches of both East and South Forks when sufficient flow occurs to enable upstream passage to those areas. It is possible that fall Chinook spawning has been extended upstream since spring Chinook salmon were extirpated in the 1970s. Besides spawning in the mainstem Scott River, the modeling assumed that fall Chinook can spawn in the lower reaches of the larger tributaries up to a channel gradient of about 3%. These tributaries included Kelsey Creek, Canyon Creek, Sniktaw Creek, Shackleford-Mill creeks, Moffett Creek, Kidder Creek, Patterson Creek, and Etna Creek. Spawning was allowed in the model in all stream reaches downstream of those upper limits. This distribution of spawners allowed in the model does not necessarily mean that spawning in all these locations would be successful at producing returning adults—whether spawning could be sustained at these sites would depend on the success of a full life cycle being initiated there. The same spawning distribution was allowed in each scenario being modeled.

The timing of fall Chinook life stages (periodicity) assumed for modeling was obtained from the fife stage periodicity information for the Klamath River described in USFWS (1998).

The fecundity of Chinook salmon applied in the model is derived from applying estimates of eggs per female spawner together with estimates of age composition and sex ratio by age. Information contained in Synder (1931), Moffett and Smith (1950), and Sullivan (1989) was reviewed and incorporated. That information was used in setting the parameters for eggs per female, age composition, and sex ratio by age. The smolt to adult survival rate (SAR) also was incorporated because of how the SAR affects age composition of fish returning to natal river. Parameters were set recognizing that Klamath River fall Chinook salmon appear to reflect a generally younger mean age composition compared to Chinook salmon populations both further north and those to the south (Central Valley), which results in relatively low eggs per female and eggs per spawner compared to other populations (Healey and Heard 1984; Healey 1991).

Using these model inputs, the EDT model produced age structures and average eggs per spawner applied in the modeling for the fall and spring-run Chinook salmon for the two baseline scenarios as listed in Table 4-4. It is important to recognize that these modeling values represent the age structure and average eggs per female that would occur in the spawning populations in the absence of all fishing. There is uncertainty associated with the values because uncertainties exist in available information and the effects of fishery selectivity on age structure and associated fecundities.

Table 4-4. Age structure and associated eggs per spawner produced by the EDT model for Scott River fall and spring-run Chinook salmon using model inputs drawn from literature sources cited in the text.

Population	Baseline	Age 2	Age 3	Age 4	Age 5	Age 6	Eggs per spawner
Fall Chin	Hist	19%	33%	42%	6%	0%	1,620
	Curr	19%	33%	42%	6%	0%	1,598
Spr Chin	Hist	20%	33%	41%	5%	0%	1,566
	Curr	20%	34%	40%	5%	0%	1,555

For comparison to values derived through the EDT modeling, the average fecundity of wild Klamath River female Chinook salmon given in Synder (1931) can be used to calculate eggs per spawner by applying information on sex ratios. Redd counts made with spawning ground surveys are typically converted to estimates of spawner abundance by applying assumptions about sex ratio, including the number of age-2 fish (jacks or grilse). In rivers along the coast of Washington, a standardized sex ratio of 1.5 males per 1 female spawner is applied (Holt 1999; Boydstun and McDonald 2005). In the Scott River, CDFW annually estimates the number of age-2 jacks within the Chinook spawning population downstream of the adult video weir to estimate the total spawning population below the weir. A recent three year average of the total male to female ratio is 1.2 males to 1 female spawner (Knechtle and Chesney 2017; Knechtle and Guidice 2018; Knechtle and Guidice 2019). Estimates of eggs per spawner using the eggs per female given in Synder (1931) (3,760 eggs per female) and the male to female ratios mentioned above are given in Table 4-5. The estimates are consistent with those derived using the EDT modeling.

Table 4-5. Estimated eggs per spawner derived by applying assumed sex ratios to eggs per female Chinook salmon in the Klamath River from Snyder (1931). See text for sources of M:F ratios.

Eggs per female (Snyder 1931)	M:F ratio	Eggs per spawner	M:F ratio source
3,760	1.5	1,504	Ave M:F ratio used on WA coast
3,760	1.2	1,709	3-yr ave from Scott River

The remainder of this section with the exception of the last two paragraphs is extracted from Lestelle (2013), which was a technical memorandum I prepared for the Yurok Tribe to estimate the historical run sizes of Scott River salmon populations, including Chinook salmon. The description of juvenile Chinook life histories is informative to this report. Rather than rephrasing that material, I decided to simply present it here because of its relevance and completeness.

Healey (1991) described the life histories of Chinook around two patterns of freshwater residence by juveniles. The patterns, which were originally identified by Gilbert (1912) based on scale analysis and presence of a winter growth check, classify juvenile life history based on age at outmigration. Ocean-type fish are those that outmigrate as sub-yearlings, usually migrating to sea within six months (though sometimes more than six months) of fry emergence. Stream-type fish are those that migrate seaward in spring of their second year of life, or in far northern populations in their third year of life. Stream-type Chinook are typically found in rivers north of 56°N or in populations that spawn in the high elevation upper reaches of long rivers such as the Fraser and Columbia rivers. Taylor (1990) concluded that whether a population is dominated by a stream or ocean-type life history is a response to growth opportunity due to temperature and photoperiod conditions and distance from the sea. Miller and Brannon (1982) concluded that temperature regimes are the driving factor, with populations adapted to the combination of emergence timing, subsequent growth rates, and marine conditions at ocean entrance. Particularly cold conditions during egg incubation and early fry rearing, resulting in slower development and growth, are more likely to produce the stream-type life history.

Between 56°N and the Columbia River both life history patterns are present (Healey 1991; Lichatowich and Mobrand 1995), with the dominant type in a population being determined by prevailing freshwater temperature regimes. Washington coastal populations and those south of the Columbia River are dominated by the ocean-type life history (Nicholas and Hankin 1988; Healey 1991; Lichatowich and Mobrand 1995; Williams 2006).

Considerable confusion has occurred in the Pacific Northwest as a result of a generalization made by Healey (1991) that most spring Chinook populations have a stream-type life history (discussed in Lichatowich and Mobrand 1995; Lestelle et al. 2005b; Williams 2006). Healey (1991), while recognizing exceptions, associated the stream-type form with adult spawning migrations in the spring and summer and the ocean-type form with adult spawning runs in late summer and fall. As a result, many biologists, including some in California, have mistakenly assumed that the dominant life histories of spring Chinook in general are the same as those in the upper Columbia and Fraser systems, i.e., having a stream-type life history. In regards to Healey's generalization, Lichatowich and Mobrand (1995) concluded the following:

> *"This generalization breaks down, however, on the California, Oregon and Washington coasts where the spring Chinook runs are often comprised of a significant proportion of fish with ocean type life histories. For example, in the Rogue River, 95 percent of the adult spring Chinook exhibit the ocean type life history pattern (Nicholas and Hankin 1989)."*

Two examples of what appear to be a misapplication of the two life history patterns described by Healey (1991) are seen in Barnhart (1994) and Moyle (2002), both relevant to my analysis. In the first example, Barnhart (1994) described life history patterns of Chinook in the Klamath basin as comprised of three types:

> Type I – juvenile outmigration (seaward movement) occurs in spring and early summer within a few months of fry emergence from the spawning gravels;
>
> Type II – juveniles rear through spring and summer within the natal stream, then outmigrate to the ocean in the fall; and

Type III – juveniles rear within freshwater for approximately one year after fry emergence and outmigrate in spring of the second year of life to the ocean.

Barnhart referred to both Type II and Type III fish as being stream-type, though he did not explain why the Type II life history was considered stream-type. It is noted, however, that biologists in California often refer to a fish that emigrates in fall as a yearling based not on formation of a winter annulus on scales but on the anniversary of egg deposition (e.g., CDFG 1998).

In the second example, Moyle (2002) described the dominant juvenile life history pattern of California spring Chinook as exhibiting "a classic stream-type life history pattern", while recognizing that juveniles rear in the streams for 3-15 months, depending on flow conditions. In contrast, Williams (2006) presented a lengthy summary of life history information for Central Valley Chinook, then concluded that most spring Chinook in that region were historically ocean-type. He suggested that stream-type fish may have been more common than exists currently due to higher elevation habitats (colder) in the San Joaquin system having been blocked by dams. Williams' conclusion is consistent with coast-wide patterns of life history described earlier.

Moyle et al. (2008) provided additional information on Klamath spring Chinook life history, which made it clear that historical spring Chinook in Salmon River were largely ocean-type. The authors noted that Snyder (1931) had analyzed scales from 35 spring Chinook returning to Salmon River and found that 83% displayed ocean-type growth patterns.

I conclude on the basis of the foregoing that it is very likely that the large majority of Scott River Chinook historically exhibited the ocean-type life history, whether they were spring or fall-run fish. It would be expected, however, that some relatively small portion of the aggregate juvenile Chinook population produced had a stream-type life history, which commonly occurs in populations on the Washington and Oregon coasts. I note that in a recent review of salmon life histories in the Shasta River, I concluded that the historical spring Chinook there were very likely dominated by the ocean-type life history (Lestelle 2012). The Shasta River, with its abundance of spring water and rich invertebrate production, would have been highly favorable to the ocean-type form. Though different in hydrology and natural nutrient loading, the Scott River valley historically should have warmed sufficiently and also been rich enough in invertebrates to be most favorable to the ocean-type form.

For this application using the EDT model, both the fall and spring Chinook populations in the Scott River were modeled assuming that 100% of the juvenile outmigrations were comprised of ocean-type life histories. In actuality, a very small percentage of outmigrants moving past the rotary screw trap (RST) in the lower Scott River are age-1 smolts. For example, in 2018, Massie and Anderson (2019) estimated that approximately 411,000 age-0 Chinook juveniles migrated past the RST. They also estimated that approximately 1,000 age-1 Chinook smolts passed the trap, which is about 0.2% of the total juvenile Chinook that passed the trap in that year. The age-1 Chinook life history pattern was not included in the EDT modeling.

The outmigrant age-0 Chinook juveniles moving out of Scott River exhibit two distinct patterns typically seen in ocean-type Chinook populations along the coasts of California, Oregon, and Washington. The two patterns are described in Healey (1991). The first pattern consists of newly emerged Chinook fry that disperse rapidly downstream following emergence—these fish have been called fry migrants. This pattern is clearly evident in the annual reports for the Scott River RST prepared by CDFW, such as seen in Massie and Anderson (2019). A second pattern consists of larger fish (greater than approximately 45 mm) that occurs somewhat later than the fry migrants—these fish are often referred to as parr or fingerling migrants. This pattern is also clearly evident in the data collected at the Scott River RST. This second group of fish move more slowly than fry migrants, exhibiting a rearing type migration, meaning they feed and grow as they continually move seaward. Both of these patterns were incorporated into the EDT model. I reviewed the information contained in recent CDFW reports for the RST trapping project and concluded that, on average, about 60% of the Chinook juveniles moving past the RST were fry migrants. The model was configured to produce roughly a 60:40 split in the juveniles moving out of Scott River. It bears noting that fry migrants typically slow their migration speed at some point and switch to a rearing-type migration. The EDT model provided this transition.

4.1.3.3. Spring Chinook Salmon

To model the spring Chinook population, spawner distribution was assumed to occur generally upstream of the spawner distribution of fall Chinook salmon, though some spatial overlap was assumed. It is noted that the modeling distribution is an assumption—no documentation exists to my knowledge that describes what the distribution was prior to the extirpation. I made what I considered to be reasonable assumptions about overlapping spawning distributions for both spring and fall Chinook salmon based on many years of observations on spawning distribution patterns in Western Washington for these two run-types.

The downstream end of spring Chinook spawning on the mainstem Scott River was assumed to occur at Etna Creek (RM 42). Besides spawning in the mainstem Scott River, the modeling assumed that spring Chinook would have spawned in the larger tributaries upstream of Etna Creek (including in Etna Creek) up to a channel gradient of about 3%. These tributaries included French Creek, Sugar Creek, and South and East Forks, including Grouse Creek and Kangaroo Creek. This distribution of spawners allowed in the model does not necessarily mean that spawning in all these locations would have been successful at producing returning adults—whether spawning could have been sustained at these sites would have depended on the success of a full life cycle being initiated there. The same spawning distribution was allowed in each scenario being modeled.

The age structure and eggs per spawner derived from the modeling were given in Table 4-4.

Juvenile life history patterns applied in the modeling are basically the same as those used in modeling fall Chinook though somewhat earlier emergence and outmigration were assumed to occur based on patterns seen in Western Washington rivers where both run-types exist (e.g., SIT and WDFW 2017, Gilbertson et al. 2021).

4.2. Results of Baseline Analysis

Baseline performance results for both historical and current conditions for each of the three salmon populations are presented separately below.

4.2.1. Coho Salmon Baseline Performance

The modeling results depict a massive decline in coho salmon performance in the Scott River subbasin over roughly the past 200 years. The equilibrium abundance (Neq) was estimated to drop by approximately 98% over this period. This loss is reflected in each of the VSP metrics evaluated by the model and is shown to have occurred to each of the major population components (Table 4-6 and Figure 4-1).

The results are summarized for each of four population components used to distinguish major spawning aggregations by area (Table 4-6 and Figure 4-1). The results are given for the aggregate combined spawning population (entire subbasin) and for four spawning aggregations delineated by major areas of the subbasin: (1) Forks – South and East Fork combined; (2) Upper valley – all stream reaches downstream of the forks and upstream of Etna Creek (including Etna Creek); (3) Lower valley – all stream reaches downstream of Etna Creek and upstream of the USGS flow gauging station just downstream of the valley; and (4) Canyon – all stream reaches downstream of the USGS gauging station and upstream of the confluence with the Klamath River.

Table 4-6. Coho salmon performance measured at the spawner life stage based on EDT modeling for the historical and current baselines for the four major spawner aggregations assessed in the model. Numbers reflect performance absent any harvest in the ocean or river.

Population component	Population performance metrics								Percent change from historical to current			
	Historical				Current							
	Neq	Cap	Prod	LHD	Neq	Cap	Prod	LHD	Neq	Cap	Prod	LHD
All	16,071	17,579	12.0	98.5%	415	676	2.7	5.0%	-97.4%	-96.2%	-77.8%	-95.0%
Forks	1,818	1,995	11.3	98.3%	43	83	2.1	0.9%	-97.6%	-95.8%	-81.6%	-99.0%
Upper valley	3,742	4,051	13.1	97.9%	193	303	2.8	14.0%	-94.8%	-92.5%	-79.0%	-85.7%
Lower valley	10,334	11,295	11.8	98.8%	130	244	2.1	1.3%	-98.7%	-97.8%	-81.7%	-98.7%
Canyon	171	237	3.6	6.1%	21	46	1.8	0.1%	-87.7%	-80.4%	-49.2%	-98.4%

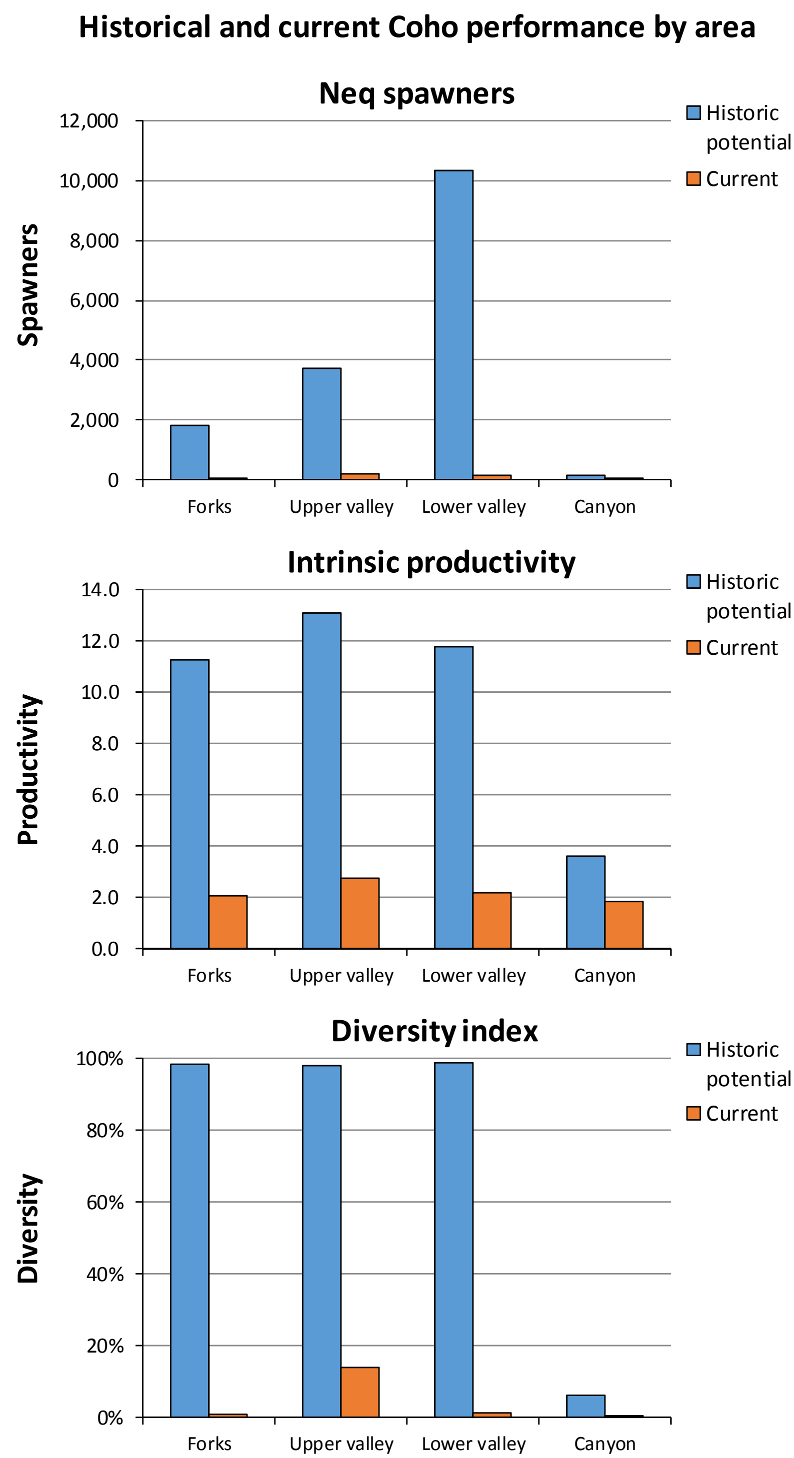

Figure 4-1. Historical and current baseline coho salmon performance based on EDT modeling for the major spawner aggregation areas assessed with the EDT model.

The overall pattern of changes between historical and current performance is a sharp reduction in each performance metric. For the aggregate subbasin population, the model estimated a 97% decline in Neq, a 78% decline in productivity, and a 95% loss in the life history diversity index. All four of the geographic areas modeled showed sharp losses, but the percentage decline was less for the canyon subpopulation though that component is a very small part of the overall population in the subbasin.

The Neq under current condition was projected by the model to be approximately 400 adult fish with a population productivity <3.0 adult recruits/spawner and a life history diversity index of 5%. The model estimated the Neq under historical conditions to be approximately 16,000 adult spawners with a productivity of 12.0 and a life history diversity index >98%. I remind the reader that these equilibrium run sizes represent geometric means as projected by the model. Actual observed run sizes—if the data were available—in some years would have substantially exceeded these values due to variability in survival factors; similarly run sizes in some years would have been much lower than those projected by the model.

The productivity estimate for the aggregate population in the current baseline of 2.7 adult recruits/spawner is low and is indicative of a population at risk. The estimated productivities for the subpopulations spawning in the forks and in the lower valley of 2.1 adult recruits/spawner are especially low. These productivity values indicate that there is very little resilience in the population to cope with environmental variability and further deterioration in habitat quality.

Similarly, the life history diversity index values are also very low (5% for the aggregate population), also showing that there is little resilience in the population to protect it from environmental variability. The pattern of such low life history diversity currently functioning means that the population is highly fragmented with relatively few small groups of spawners persisting in isolated areas.

The model projected S-P curves for adult spawners are depicted in Figure 4-2 for the aggregate spawner populations. Displayed in this way, the reader can easily see that the existing population—as projected by the model—is performing at dangerously low levels. All of the VSP metrics suggest that the population is at high risk of extinction.

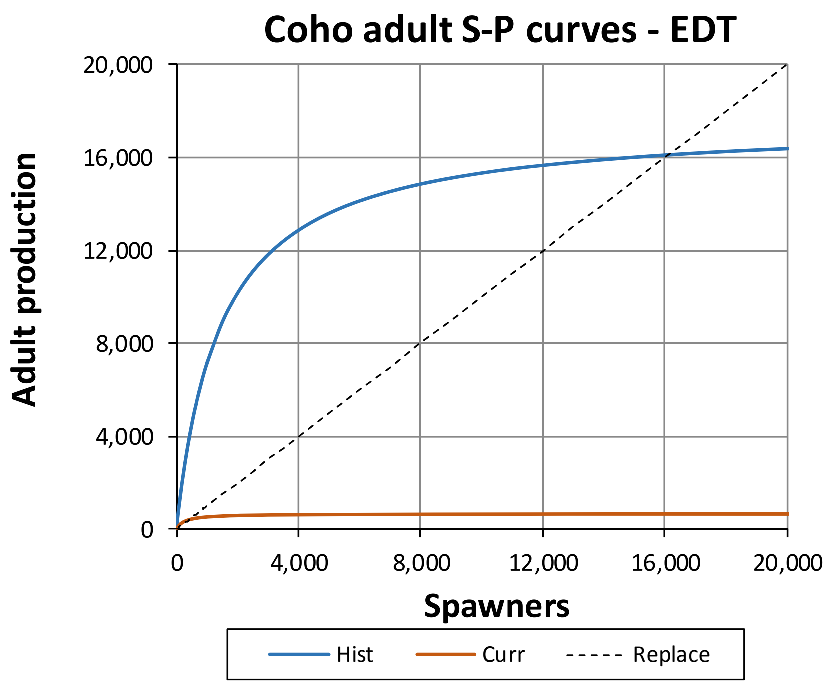

Figure 4-2. Historical and current baseline S-P relationships for coho salmon measured at the spawner life stage derived from EDT modeling.

It bears noting that the model projects Neq values in the absence of all fishery harvests. Estimated ocean exploitation rates on Klamath River coho salmon averaged about 5% for 2007 to 2013 (Simondet 2014). More recent rates have likely been less. In-river harvest of coho salmon is minimal. It is likely that the current total exploitation rates on Klamath River coho salmon is <5%. This means that there is very little relief that can be obtained for the population with further restrictions in fisheries.

The EDT Model also gives estimates of smolt yield (equilibrium levels) from a river system, along with estimated capacity and productivity (smolts per spawner at low spawner density) (Table 4-7; Figure 4-3). The Neq smolt yields for the historical and current condition baselines were estimated to be approximately 327,400 and 9,100 fish respectively. The number of smolts produced from spawning within the canyon stream reaches is not included in the table or the figure, though those numbers would be very small relative to smolts produced by spawners upstream of the canyon.

Table 4-7. Coho salmon performance measured at the smolt life stage based on EDT modeling for the historical and current baselines for the four major spawner aggregations assessed in the model.

Population component	Smolt population performance metrics						Percent change from historical to current		
	Historical			Current					
	Neq	Cap	Prod	Neq	Cap	Prod	Neq	Cap	Prod
All	327,409	358,341	238.6	9,104	14,719	60.5	-97.2%	-95.9%	-74.6%
Forks	37,100	40,890	220.2	979	1,929	46.2	-97.4%	-95.3%	-79.0%
Upper valley	76,465	83,027	258.5	4,418	6,982	62.3	-94.2%	-91.6%	-75.9%
Lower valley	213,734	234,424	234.3	3,061	5,808	49.7	-98.6%	-97.5%	-78.8%

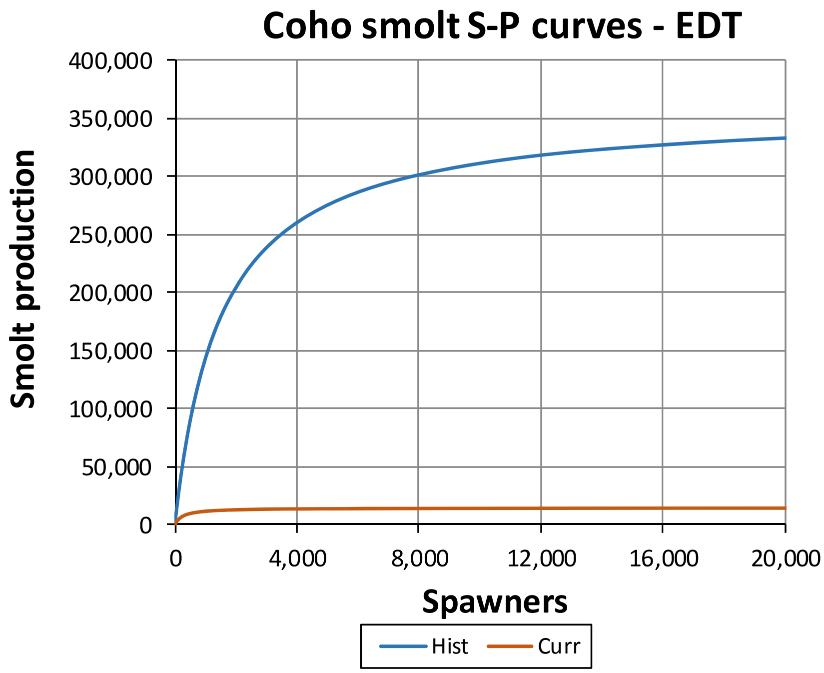

Figure 4-3. Historical and current baseline S-P relationships for coho salmon measured at the smolt life stage derived from EDT modeling.

To help validate the model for coho salmon, I compared model outputs to estimates of total adult coho spawner abundances returning to the Scott River based on CDFW video weir estimates. Data for return years 2010-2018 are from Knechtle and Giudice (2019); the preliminary estimate for return year 2019 is from Morgan Knechtle (CDFW, pers. comm.) (return years 2010-2019 are from brood years 2007-2016). Figure 4-4 displays the EDT derived S-P curve for the current condition baseline to the plotted empirical data along with the estimated S-P curve derived from the empirical data. Table 4-8 compares estimates of equilibrium abundance, capacity, and productivity for the EDT B-H spawner production curve to the estimates based on curve fitting to the empirical data for both a B-H curve and a Ricker shaped curve[10] (Hilborn and Walters 1992). I compare the EDT-derived metrics here for both the B-H and Ricker fitted curves because B-H fitted curves tend to overestimate the productivity parameter and the Ricker productivity value is generally considered more accurate (Walters and Martell 2004). However, the asymptotic shape of the B-H curve is generally considered more appropriate for coho salmon, while the shape of a Ricker curve is inconsistent with the life history and ecology of the species (Lestelle et al. 1984; Bradford et al. 1997)—this means that estimates of capacity and Neq based on the Ricker fit are usually inappropriate for this species.

[10] / The Ricker form of the S-P relationship is dome shaped, showing decreasing production of progeny at high spawning escapements. This form is generally considered to be appropriate for species like pink and chum salmon that are often limited in abundance by the amount of spawning habitat instead of freshwater rearing habitat.

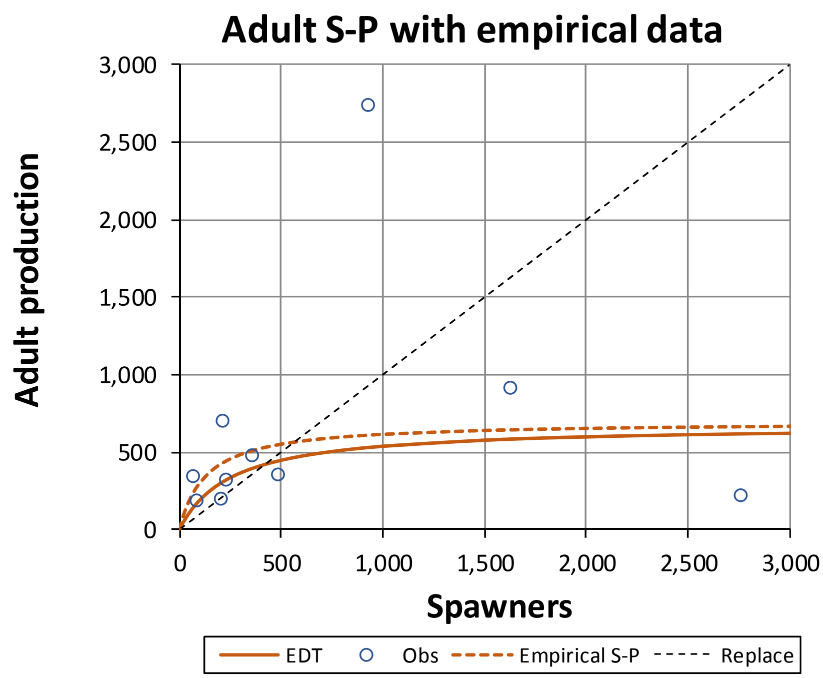

Figure 4-4. S-P relationships for coho salmon measured at adult life stage derived from EDT modeling (solid orange) and from estimated adults passing the video weir near the top end of canyon (dashed orange). Video weir estimates (Obs) for 2010-2018 are from Knechtle and Giudice (2019); preliminary estimate for return year 2019 is from Morgan Knechtle (CDFW, pers. comm.). The fitted curve assumes a B-H relationship.

Table 4-8. Summary of parameter estimates comparing EDT results to those obtained by fitting S-P curves to the empirical data using both a B-H relationship and a Ricker relationship. The geometric mean of adult coho passing the video weir (452) in 2010-2019 is also shown.

Method	Neq	Cap	Prod
EDT	415	676	2.7
Empirical S-P Bev-Holt	567	697	5.3
Empirical S-P Ricker	892	892	2.8

Weir geometric mean	452

The EDT productivity estimate for the current baseline is 2.7 adult returns/spawner, compared to 2.8 adult returns/spawner using the Ricker fit to the empirical data—a close match. The B-H fit to the empirical data produced an estimate of 5.3 adult returns/spawner, which is substantially higher, but as noted above, the B-H fit is often biased high.

The Neq and capacity estimates produced with the B-H fit to the empirical data produced very close matches to the EDT estimates: Neq of 567 vs 415 fish and capacity of 697 vs 676 fish, respectively. The geometric mean of the estimates of adult spawners passing the CDFW weir in 2010-2019 was 452 fish, a close match to the EDT Neq estimate. As noted above, the EDT estimate is meant to represent the number of spawners that would occur in the absence of all fishery mortality, while the empirical estimate of average spawners is after all fishery mortality occurs. Average total exploitation on Scott River coho is almost certainly very low so making these comparisons is appropriate.

Another comparison can be made for estimated outmigrant smolts from the EDT model to estimated smolts at the rotary screw trap (RST) operated by CDFW in the lower Scott River (see Table 3-4; Figure 4-5). The geometric mean of estimated smolt yields in 2003-2019 at the RST was approximately 8,400, though the range over these years is very large (353 to 73,232; Table 3-4), demonstrating extremely high interannual variation in smolt yield. (No smolt estimates were made in 2004 and 2017.) The EDT model estimates the number of smolts entering the estuary so the numbers are not directly comparable. Still, the estimate of Neq smolts entering the estuary (approximately 9,100) based on modeling for the current baseline conditions is within 10% of the empirical geometric mean estimate of smolts estimated to pass the RST in the lower Scott River.

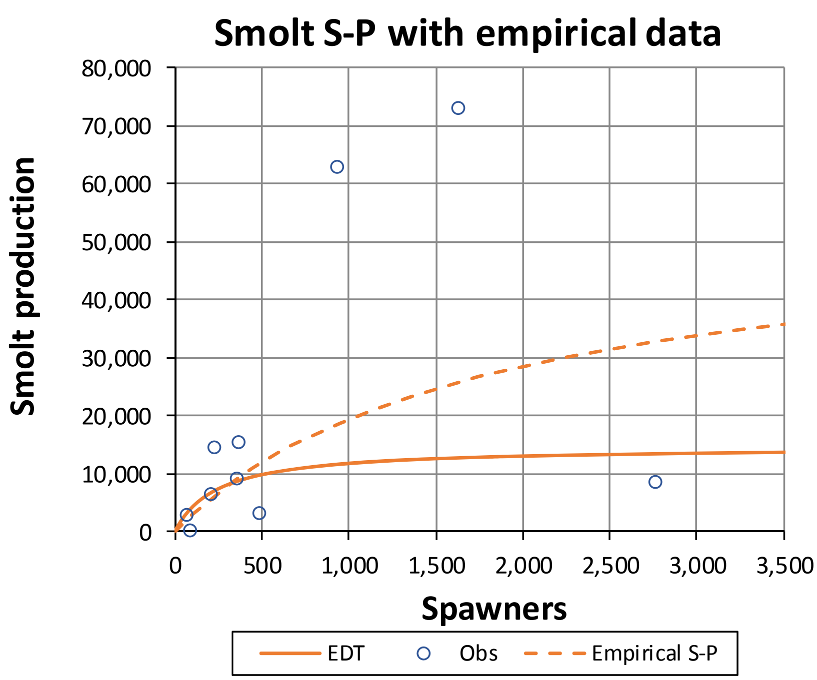

Figure 4-5. S-P relationships for coho salmon measured at the smolt life stage derived from EDT modeling (solid orange) entering the Klamath River estuary and from estimated smolts passing the rotary screw trap (RST) operated near the bottom end of the canyon (dashed orange). Smolt estimates (Obs) are from CDFW (Massie and Patterson 2019). The fitted curve assumes a B-H relationship.

All of these modeling results incorporate effects of environmental changes in both the Scott River subbasin and in the mainstem Klamath River. As described in Section 4.1.2, the modeling incorporated assumptions about the effects of *C. shasta* that could be expected to accrue in the mainstem Klamath River during the juvenile coho outmigration. Based on the pattern of *C. shasta* distribution and exposure by outmigrating juvenile coho assumed in the model, the effect on coho intrinsic productivity is seen in Table 4-9. The overall effect was projected to be relatively modest. The large majority of the decline in coho population performance was projected to occur within the Scott River subbasin. Of the total percentage change in productivity (-77.8%), 11.9% of it was estimated to occur during juvenile outmigration within the Klamath River. If the outmigrant coho juveniles experienced the same mortality in the mainstem Klamath downstream of the Scott River as under historical condition, the model would project that intrinsic productivity would be increased to 3.8. Equilibrium abundance would also be increased though not substantially.

Table 4-9. The amount of reduction in intrinsic productivity for the Scott River coho population accrued in the mainstem Klamath River during juvenile outmigration as projected by EDT modeling; expected population productivity is shown if modeling assumed conditions within the Klamath River were unchanged from historical characteristics.

Historical prod	Current prod	Total % change	% of total change accrued in Klamath R. emigration	Expected prod with historical Klamath R. effect
12.0	2.7	-77.8%	11.9%	3.8

4.2.2. Fall Chinook Salmon Baseline Performance

The modeling results demonstrate a large loss in fall Chinook salmon performance between the historical and current baselines. The loss is reflected in each of the VSP metrics evaluated by the model and has occurred in each of the major population components.

The results are summarized for each of three population components used to distinguish the major spawning aggregations by geomorphic area (Table 4-10 and Figure 4-6). The population was delineated by three spawning aggregations: (1) Upper valley – all stream reaches downstream of the forks and upstream of Etna Creek (including Etna Creek); (2) Lower valley – all stream reaches downstream of Etna Creek and upstream of the USGS flow gauging station just downstream of the valley; and (3) Canyon – all stream reaches downstream of the USGS gauging station and upstream of the confluence with the Klamath River.

Table 4-10. Fall Chinook salmon performance measured at the spawner life stage based on EDT modeling for the historical and current baselines for the three major spawner aggregations assessed in the model. Numbers reflect performance absent any harvest in the ocean or river.

Population component	Population performance metrics								Percent change from historical to current			
	Historical				Current							
	Neq	Cap	Prod	LHD	Neq	Cap	Prod	LHD	Neq	Cap	Prod	LHD
All	18,451	20,266	11.2	100%	5,596	7,044	4.9	68%	-69.7%	-65.2%	-56.4%	-31.9%
Upper valley	2,034	2,199	13.3	100%	360	498	3.6	81%	-82.3%	-77.3%	-72.9%	-19.1%
Lower valley	11,622	12,781	11.0	100%	2,188	3,087	3.4	51%	-81.2%	-75.8%	-68.9%	-49.3%
Canyon	4,795	5,286	10.8	100%	2,840	3,459	5.6	96%	-40.8%	-34.6%	-48.1%	-4.2%

The overall pattern of changes between historical and current performance is a large reduction in each performance metric. For the aggregate subbasin population, the model estimated a 70% decline in Neq, a 56% decline in productivity, and a 32% loss in the life history diversity index. While each of the three spawning aggregations modeled showed large losses, the loss was much less for the canyon spawning aggregation. For that population component, Neq was estimated to have declined by approximately 40%. The life history diversity index for that component dropped by only about 4%. These results reflect a relative magnitude of difference in how much the habitats within the valley have been altered compared to those within the canyon, as these areas are used by fall Chinook salmon.

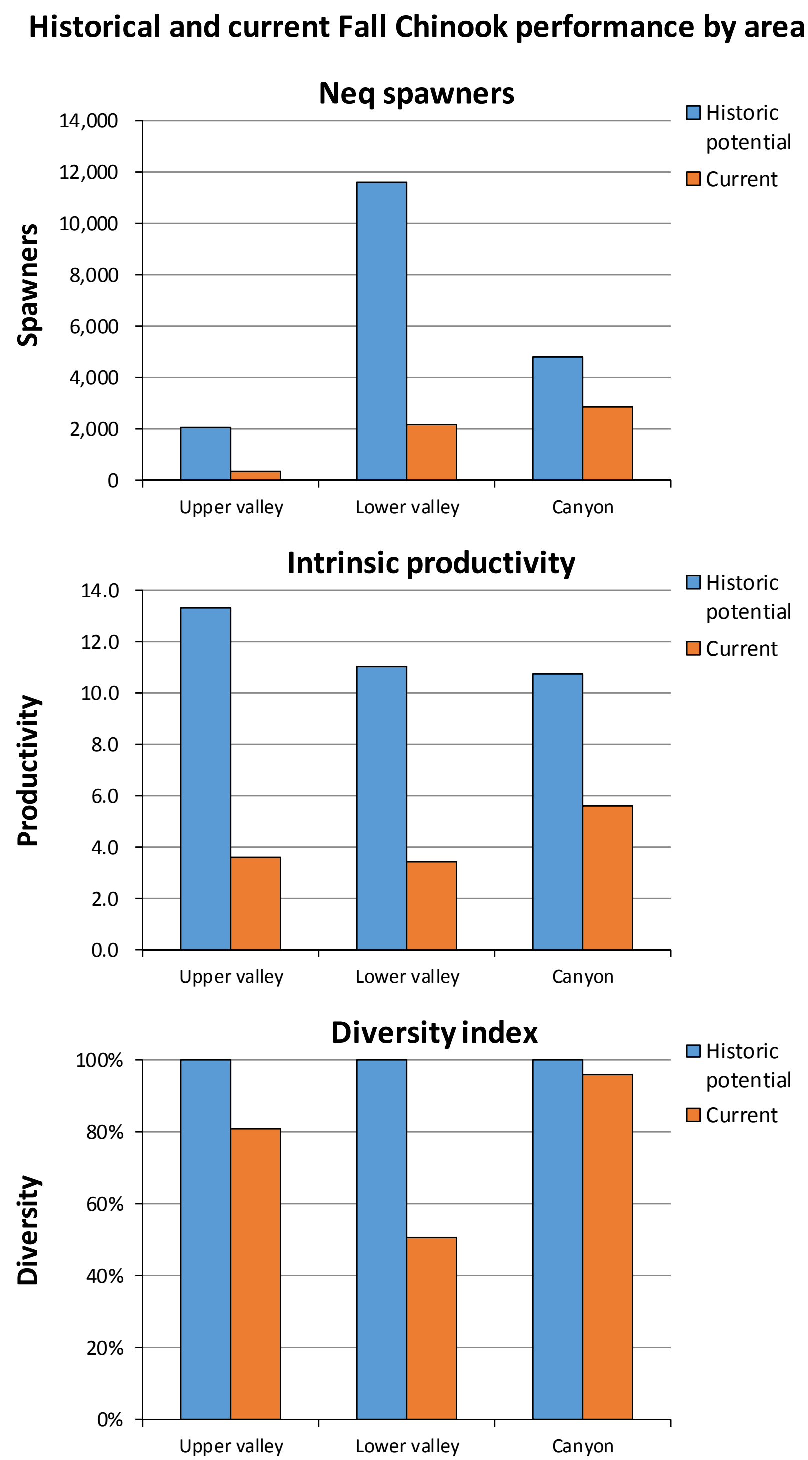

Figure 4-6. Historical and current baseline fall Chinook salmon performance based on EDT modeling for the major spawner aggregation areas assessed with the EDT model.

The Neq under current condition was projected by the model to be approximately 5,600 adult fish with a population productivity of 4.9 adult recruits/spawner and a life history diversity index of 68%. The model estimated the Neq under historical conditions to be approximately 18,500 adult spawners with a productivity of 11.2 and a life history diversity index of 100%. I remind the reader that these equilibrium run sizes represent geometric means as projected by the model. Actual observed run sizes—if the data were available—in some years would have substantially exceeded these values due to variability in survival factors; similarly run sizes in some years would have been much lower than those projected by the model.

To help validate the model for fall Chinook salmon, I compared model outputs to estimates of adult fish returning to Scott River (Table 3-7). Estimates of returning fall Chinook salmon to the Scott River are based on CDFW video weir counts expanded for the estimated number of fish spawning downstream of the counting weir (Knechtle and Giudice 2019). These estimates do not account for the number of fish harvested in the ocean or freshwater prior to returning to the Scott River, whereas the EDT estimates are the number of fish prior to harvest.[11] Therefore, I adjusted the 10-year empirical geometric mean estimate of spawning escapement (2,845; years 2009-2018 in Table 3-7) by the estimated average exploitation rate for 2009 to 2018 based on data in KRTT (2019; Table 3 in that document). The 10-year average total exploitation rate for Klamath River fall Chinook salmon is estimated to be 48%.[12] The estimated geometric mean spawning escapement of 2,845 expands to 5,471 adults in the absence of harvest (2,845 ÷ (1 – 0.48)), which is a close match to the EDT Neq abundance estimate of 5,600 fish.

The model projected S-P curves for adult spawners are depicted in Figure 4-7 for the aggregate spawner populations.

While the performance of Scott River fall Chinook salmon has declined sharply from historical estimates based on modeling, the results suggest that the aggregate population should be reasonably stable though in a much reduced state of performance. However, the productivity values for the valley population components of about 3.5 adult recruits/spawner suggest that these component subpopulations may be at risk of continued, even accelerated loss under existing conditions. Accounting for average harvest losses, the productivity rate of the fish returning to the Scott Valley after harvest would be about half of the 3.5 value, reducing it to roughly 1.8 adult recruits/spawner returning to the spawning grounds upstream of the canyon. This suggests that the performance of these component subpopulations may be precariously close to collapse if conditions within the river continue to deteriorate and/or interannual environmental variability increases (either in the ocean or in-river).

---

[11] / EDT estimates represent the number of fish that would return to the spawning grounds in the absence of all fisheries.

[12] / Estimates in KRTT (2019) are annual harvest rates for calendar years but the rate to be applied to the EDT Neq abundance value should be for brood years and for all ages returning from those brood years. A reasonable approximation of the brood year exploitation rate is obtained by adding the annual ocean harvest rate for age-4 fish to the annual in-river harvest rate for age-4 fish (Dr. Gary Morishima, member of the Chinook Technical Committee for the Pacific Salmon Commission, personal communications).

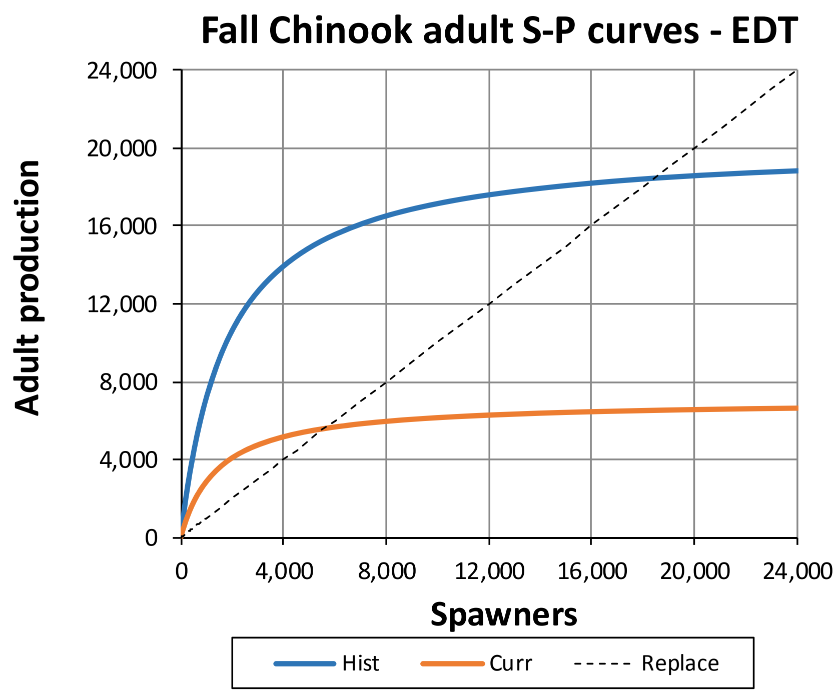

Figure 4-7. Historical and current baseline S-P relationships for fall Chinook salmon measured at the spawner life stage derived from EDT modeling.

All of these modeling results incorporate effects of environmental changes in both the Scott River subbasin and in the mainstem Klamath River. As described in Section 4.1.2, the modeling incorporated assumptions about the effects of *C. shasta* that could be expected to accrue in the mainstem Klamath River during the juvenile fall Chinook outmigration. Based on the pattern of *C. shasta* distribution and exposure by outmigrant fall Chinook assumed in the model, the effect on intrinsic productivity is seen in Table 4-11. Most of the decline in the fall Chinook population performance was projected to occur within the Scott River subbasin. Of the total percentage change in productivity (-56.4%), 25.7% of it was estimated to occur during the juvenile outmigration within the Klamath River. If the outmigrant coho juveniles experienced the same mortality in the mainstem Klamath downstream of the Scott River as under historical condition, the model would project that intrinsic productivity would be increased to 6.5. Equilibrium abundance would also be increased.

Table 4-11. The amount of reduction in intrinsic productivity for the Scott River fall Chinook population accrued in the mainstem Klamath River during juvenile outmigration as projected by EDT modeling; expected population productivity is shown if modeling assumed conditions within the Klamath River were unchanged from historical characteristics.

Historical prod	Current prod	Total % change	% of total change accrued in Klamath R. emigration	Expected prod with historical Klamath R. effect
11.2	4.9	-56.4%	25.7%	6.5

4.2.3. Spring Chinook Salmon Baseline Performance

The modeling results depict an enormous loss in spring Chinook salmon performance between the historical and current baselines. The population is believed to have been extirpated in the early 1970s (Moyle 2002). The loss is reflected in each of the VSP metrics evaluated by the model and shows similar magnitudes of decline in each of the major population components that were modeled. Although the VSP metrics at first glance might suggest that spring Chinook could still inhabit the river system, the results on closer inspection do not support that.

EDT modeling results are summarized for each of three population components used to distinguish the major spawning aggregations by geomorphic area (Table 4-12 and Figure 4-8). The population was delineated by three spawning aggregations: (1) Upper valley – all stream reaches downstream of the forks and upstream of Etna Creek (including Etna Creek); (2) South Fork – all stream reaches in the South Fork; and (3) East Fork – all stream reaches in the East Fork. Modeling results are given for historical and current environmental conditions for equilibrium spawner abundance (Neq), capacity, productivity, and life history diversity. Percent changes from average historical performance to average current performance are also provided in Table 4-8.

Table 4-12. Spring Chinook salmon performance measured at the spawner life stage based on EDT modeling for the historical and current baselines for the three major spawner aggregations assessed in the model. Numbers reflect performance absent any harvest in the ocean or river.

Population component	Population performance metrics								Percent change from historical to current			
	Historical				Current							
	Neq	Cap	Prod	LHD	Neq	Cap	Prod	LHD	Neq	Cap	Prod	LHD
All	3,406	4,066	6.2	100%	309	547	2.3	19%	-90.9%	-86.5%	-62.6%	-80.9%
Upper valley	885	1,055	6.2	100%	99	190	2.1	22%	-88.8%	-82.0%	-66.3%	-77.6%
South Fork	259	314	5.8	100%	54	91	2.4	56%	-79.2%	-70.8%	-57.9%	-44.4%
East Fork	2,262	2,697	6.2	100%	150	266	2.3	13%	-93.4%	-90.2%	-63.0%	-86.9%

The overall pattern of changes between historical and current performance is a sharp reduction in each performance metric. For the aggregate subbasin population, the model estimated a 91% decline in Neq, a 63% decline in productivity, and an 81% loss in the life history diversity index. All of the three geographic areas modeled showed sharp losses but with slightly less loss in the South Fork.

The Neq under current condition was projected by the model to be approximately 300 adult fish with a population productivity of 2.3 adult recruits/spawner and a life history diversity index of 19%. The model estimated the Neq under historical conditions to be approximately 3,400 adult spawners with a productivity of 6.2 and a life history diversity index of 100%. I remind the reader that these equilibrium run sizes represent geometric means as projected by the model. Actual observed run sizes—if the data were available—in some years would have substantially exceeded these values due to variability in survival factors; similarly run sizes in some years would have been much lower than those projected by the model.

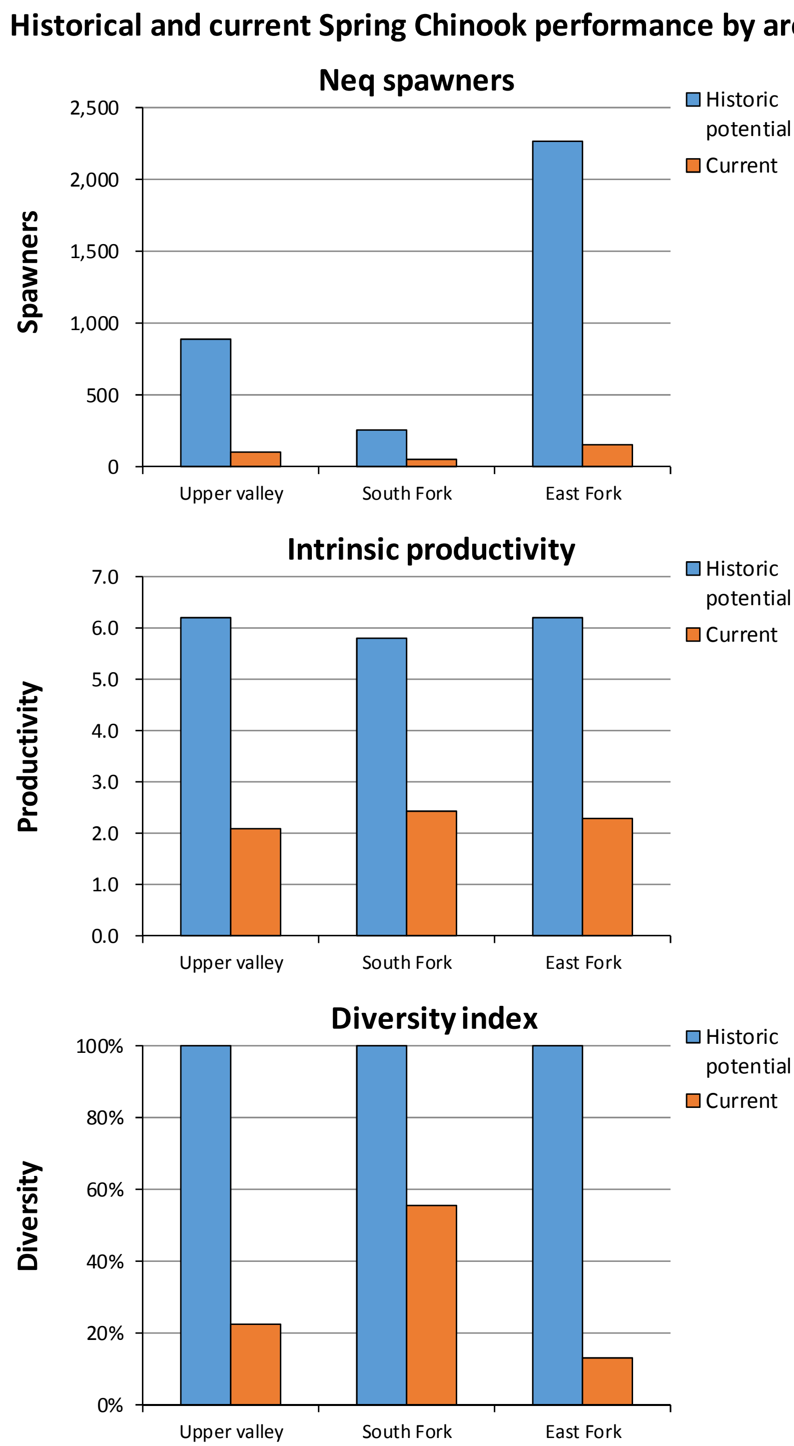

Figure 4-8. Historical and current baseline spring Chinook salmon performance based on EDT modeling for the major spawner aggregation areas assessed with the EDT model.

No data exist to validate the estimates for the current baseline period produced by the model, except for the fact that the population has been extirpated. This suggests that the model may be overestimating the current capability of the system to produce spring Chinook salmon. However, because the modeling estimates do not account for harvest loss, we need to consider what those effects would be on the model projections. Data for ocean and in-river exploitation rates on Trinity River hatchery spring Chinook salmon could potentially be used to assess current rates of exploitation on Scott River fish if they still existed. However, to my knowledge, estimates are not readily available for ocean exploitation rates on Trinity River hatchery spring Chinook salmon; CHRP (2012) stated that ocean harvest data for this stock are not available.

An alternative approach for estimating the rate of ocean harvest on Klamath River spring Chinook salmon is to consider exploitation rates on Rogue River spring Chinook salmon since both population groups are in the same Evolutionarily Significant Unit (ESU). Hankin (1990) compared ocean exploitation rates between hatchery-produced Rogue River spring Chinook salmon to hatchery-produced Klamath River fall Chinook salmon (Trinity River and Iron Gate hatcheries). The average estimated ocean exploitation rates over five years (1980-1984) were identical between the Rogue and Klamath River stocks at 59%. Klamath and Rogue River spring Chinook salmon should have similar ocean distributions, and therefore, similar ocean exploitation rates. I note that CDFG (1990) also concluded that ocean exploitation rates between spring and fall Chinook salmon produced in California are comparable. I conclude that a reasonable approximation of ocean exploitation rate on a Klamath River spring Chinook salmon population for the current baseline would be the same as described earlier for Scott River fall Chinook salmon (Section 4.2.2), i.e., 48%. Including some low level in-river harvest on spring Chinook salmon in the lower Klamath River would produce an overall exploitation rate of roughly 50%.

Applying an average exploitation rate of 50% to the EDT model's estimated productivity of 2.3 adult recruits/spawner would result in a productivity measured at the spawning grounds of 1.15 (2.3 x 0.5), slightly above the threshold value of 1.0 adult recruits/spawner, which would equate to extirpation. An average productivity value of 1.15 adult recruits/spawner would assuredly result quickly in extirpation given a normal range of variability in survival rates, either in freshwater or the ocean.

Moyle (2002) stated that extirpation occurred in the early 1970s. Total exploitation rates on the population would have exceeded 50% at that time, likely being higher than 70%. It also bears noting that extirpation occurred when summer streamflows in the mainstem Scott River dropped noticeably lower than flow levels that existed prior to 1970 – hence extirpation appears to have coincided with the increase in groundwater pumping that occurred in the valley at that time (see Sections 3.1.2 and 3.1.3) and when fishery harvest rates were especially high.

The Neq abundance for the historical population was estimated by the model to be about 3,400 fish. Moyle (2002) reported a ballpark estimate of at least 5,000 spring Chinook salmon for the historical population, which would have essentially been an educated guess. He attributed the number to CDFG (1990). Moyle gave no rationale for the 5,000 fish number. I note that CDFG (1990) does not mention any estimated abundance for the Scott River so the source and rationale for the 5,000 fish number are unknown. Regardless of the original source, I consider the two historical abundance estimates to be in the same ballpark for the sake of this assessment.

The model projected S-P curves for adult spawners are depicted in Figure 4-9 for the aggregate spawner populations. The curves illustrate that extirpation of the population under existing conditions would be certain.

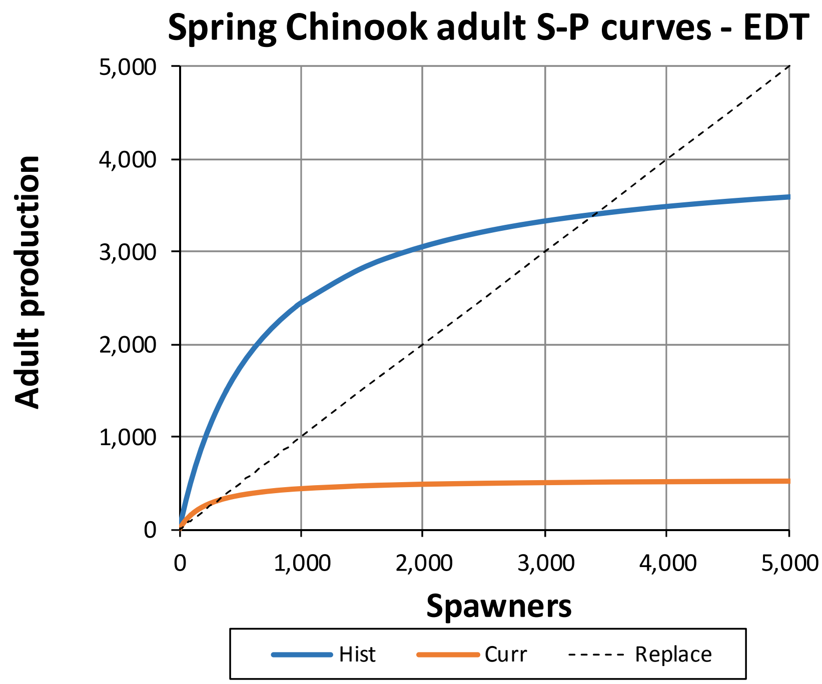

Figure 4-9. Historical and current baseline S-P relationships for spring Chinook salmon measured at the spawner life stage derived from EDT modeling.

5. Diagnosis and Prioritization

This section describes the diagnostic methods that were used in modeling, followed by results.

5.1. Diagnostic Methods

The diagnostic methods employed by the model produce three types of outputs to evaluate (1) the magnitude of decline in population performance, (2) locations in the stream system where the effects on performance are occurring, and (3) the habitat factors that are most responsible for losses in population performance. Methods to evaluate the magnitude of decline were described earlier in Section 4.1. The methods used to evaluate the "where" and "what" related to loss in population performance are described below. I note that this presentation of results is focused entirely on conditions within the Scott River subbasin and does not address environmental issues within the mainstem Klamath River.

5.1.1. Stream Reach Analysis

The EDT model was designed to produce what is commonly referred to as a stream reach analysis, which is used in diagnosing the relative importance of individual stream reaches (or groups of reaches) and each habitat survival factor associated with those reaches in affecting population performance (Blair et al. 2009).

The detailed reach structure within the model provides the means to analyze stream reach priorities for both protection and restoration. This is done in two parts – one part that analyzes the effect of degrading the reach to a standardized fully degraded reach environment (called the protection analysis) and the other part that analyzes the effect of fully restoring the reach to its historical condition (called the restoration analysis).

The protection analysis is performed by systematically assuming degraded environmental conditions for a reach (or group of reaches) – one reach at a time – and then rerunning the model with each change, and repeating this process until all reaches in the stream system have been analyzed. The protection analysis identifies the relative importance of each reach (or group of reaches) to the population under the current baseline condition. Reaches with the highest relative loss potential are important to protect. The reaches may be important because the population depends on the habitat in those reaches (e.g., a critical rearing area for juveniles) or because the predicted habitat degradation is more severe in the reach relative to other reaches under current conditions.

The restoration analysis is done in a similar way but in this case each reach (or group of reaches) is restored – one at time – to its historical condition, and then the model is rerun with the change, and the process is repeated until all reaches have been analyzed. The restoration analysis identifies the relative importance of each reach (or group of reaches) to the population for restoration compared to the current baseline condition. Reaches that produce the largest benefit from restoration are ranked highest and so on. It is important to recognize that this analysis does not take into account in any way the feasibility or cost of doing restoration that could achieve what the model assumes. This is simply a theoretical exercise that informs us about the magnitude of benefit that could be achieved if such actions could actually be done. The reader needs to be aware that by assuming full restoration of a reach in the analysis does not imply that the purpose of restoration is to restore conditions to their historical state. That is almost never achievable or desirable given the multiple land and water uses that occur within a watershed.

It bears noting that reaches identified by the modeling as producing the highest benefits from restoration are necessarily reaches that have been severely altered from their historical condition. In fact, those reaches may be so degraded that it would be extremely difficult to restore them to some normative condition to benefit the population in actuality. To address this situation, the model produces output that combines both restoration and protection benefits so that the rank of reaches for restoration work averages the results between the restoration and protection analyses. The reasoning for this way of ranking is that restoration is likely to be more effective in areas where there remains some degree of ecological function, as measured by the benefit from the protection analysis. Reaches that are the most degraded are assumed to be more difficult to restore and actions that attempt to do so are likely to be less effective than if some ecological function still remains intact.

The reach analysis also diagnoses the relative importance of environmental factors that affect population performance. It identifies the most important survival factors contributing to the loss in performance—factors that, if appropriately moderated or corrected, would produce the most significant improvements in overall population performance. This aspect of the analysis comprises an analytically derived limiting factors analysis for each stream reach specific to the salmon population being modeled.[13]

The prioritization of reaches (or groups of reaches) for restoration and protection is presented in two ways, one based on ranking stream reaches regardless of the length of the reaches and one based on normalizing (or scaling) the results based on reach length. The former set of priorities identifies the maximum possible benefit that could be achieved through full restoration of a reach (or group of reaches). The latter set of priorities identifies the amount of benefit that could be achieved per 1000 m of stream length restored.

The stream reach analysis can be performed at two scales, one at the individual reach scale, as reaches are delineated in the model, and another that combines groups of reaches into Geographic Areas (or Diagnostic Units) of relevance in diagnosis and restoration planning. Results are presented in this report at the geographic area scale; details at the reach scale can be produced though I have found that to be unwieldy and difficult to work with because of the very large amount of information produced by the model.

5.1.2. Diagnostic Geographic Areas

Geographic Areas (or Diagnostic Units) are groups of stream reaches that are defined in a way to aid the diagnosis and for potential restoration planning. The Scott River stream network was delineated into a total of 336 individual stream reaches, including reaches that are defined as structures such as diversions and culverts. Of that total, 268 stream reaches were delineated that have reach lengths >0 m. By grouping such a large number of reaches into fewer Geographic Areas, I have found the modeling results to be much more useful both for diagnosis and restoration planning. The information used to characterize habitat for the various reaches is usually insufficient to discriminate differences among reaches within an area. Therefore, caution is needed in trying to apply the modeling results at too fine of a scale.

Within the Scott River subbasin, a total of 32 Geographic Areas (or Diagnostic Units) were defined, listed in Table 5-1. Appendix D identifies stream reaches within each of the Geographic Areas.

Not all of these geographic areas are applicable to each salmon population being modeled based on how I defined the historical spawning distributions of the populations (see Section 4.1.3) and how each population's life stages utilize these geographic areas.

---

[13] / It is more correct to refer to a limiting factors analysis as a "contributing factors" analysis since most factors do not actually limit the population in the sense of life-stage bottlenecks. See discussion in Mobrand et al. (1997) on the confusion that has occurred with so-called habitat bottlenecks. Use of the term "limiting factors" is used in this report because of its widespread use by salmon biologists and habitat restoration practitioners.

Table 5-1. Geographic Areas (Diagnostic Units) delineated in the Scott River subbasin.

No.	Geographic Area (Diagnostic Unit)	Description
1	SR canyon MS lower	Scott R. mainstem within the canyon from the confluence with Klamath R. (RM 0.0) to Middle Cr. (RM 12.8).
2	SR canyon tribs	Tributaries to Scott R. within the canyon.
3	SR canyon MS upper	Scott R. mainstem within the canyon from Middle Cr. (RM 12.8) to Marilyn Cr. (RM 22.7).
4	SR valley to Kidder Cr	Scott R. mainstem within the valley from Marilyn Cr. (RM 22.7) to Kidder Cr. (RM32.4).
5	East tribs to Ft Jones	All right bank tributaries (east side) to Scott R. upstream of the canyon and downstream of Moffett Cr.
6	Sniktaw Cr	Sniktaw Cr. system.
7	Shackleford Cr	Shackleford Cr. system excluding the Mill-Emigrant Cr. system.
8	Mill-Emigrant Cr	Mill-Emigrant Cr. system (tributary to Shackleford Cr.).
9	Oro Fino Cr	Oro Fino Cr. system.
10	Moffett Cr lower	Lower Moffett Cr. system downstream of Soap Cr. (excluding Soap Cr.).
11	Moffett Cr upper	Upper Moffett Cr. system upstream of Soap Cr. (including Soap Cr.).
12	Kidder lower-Big Slough	Lower Kidder Cr. and Big Slough complex.
13	Patterson Cr	Patterson Cr. system (tributary to Kidder Cr. - Big Slough complex).
14	Crystal-Johnson Cr	Crystal Cr. and Johnson Cr. (tributaries to Kidder Cr. - Big Slough complex).
15	Kidder Cr upper	Upper Kidder Cr. system upstream of the confluence with Big Slough.
16	SR valley to Etna Cr	Scott R. mainstem within the valley from Kidder Cr. (RM 32.4) to Etna Cr (RM 42.5).
17	East Slough	East Slough complex on the right bank (east side) of Scott R. within the valley.
18	Etna Cr	Etna Cr. system.
19	SR valley to tailings	Scott R. mainstem within the valley from Etna Cr. (RM 42.5) to the downstream end of the tailings reach (RM 51.5) .
20	Clark Cr	Clark Cr. system.
21	French Cr lower	Lower French Cr. downstream of Miners Cr.; includes beaver dam complex in tributary near French Cr. mouth.
22	Miners Cr	Miners Cr. system.
23	French Cr upper	French Cr. system upstream of Miners Cr.
24	Wolford Slough	Wolford Slough complex that periodically connects to the right bank tributary to lower French Cr. This slough complex is a relect mainstem channel of Scott R.
25	SR valley to forks	Scott R. mainstem within the valley from the downstream end of the tailings reach (RM 51.5) to the forks (RM 56.8). Includes all of the tailings reaches.
26	Sugar Cr	Sugar Cr. system.
27	Wildcat Cr	Wildcat Cr. system.
28	South Fork MS	South Fork mainstem.
29	South Fork tribs	All South Fork tributaries.
30	East Fork MS lower	East Fork mainstem from the confluence with South Fork to Grouse Cr.
31	East Fork tribs	All East Fork tributaries.
32	East Fork MS upper	East Fork mainstem upstream of Grouse Cr.

5.2. Diagnostic Results

Three sets of graphic results from the modeling are used to diagnose the status of each of the salmon populations and the habitat conditions affecting their performance. The first set summarizes baseline performance—these results were presented in Section 4.2 Results of Baseline Analysis. Changes in population abundance, capacity, productivity, and the life history diversity index over the past 200 years as a result of alterations in freshwater habitat were presented. These results show the *magnitude of decline* in population performance that has occurred based on modeling.

The second set of graphics uses what have been called tornado charts to show *where* the effects of habitat alterations have had the largest adverse effects on population performance in the subbasin and where habitats are still functioning to some extent to provide population benefits. The tornado charts identify where restoration and protection actions would be most beneficial. Results are given with both stream reach lengths normalized and not normalized to account for differences in stream lengths within each of the geographic areas—both provide useful perspectives for diagnosing conditions. Normalized results show benefit per 1000 m of channel length regardless of how long the stream reach is.

The third set of graphics uses a consumer report style to indicate *what* habitat factors that affect species performance have had substantial adverse effects within each of the geographic areas. In effect, these charts show what habitat factors are most critical to restore.

5.2.1. Coho Salmon

Modeling results show that the Scott River coho population has suffered an enormous loss in performance over the past 200 years as a result of habitat alterations throughout the subbasin (see Section 4.2.1). Although no formal viability analysis has been performed, the results show that population viability is seriously threatened. The modeling results are consistent with empirical data on population abundance and trends (Figure 4-4; Table 4-8).

The tornado charts in Figures 5-1 and 5-2 rank, and categorize the ranks, by the relative importance of the different geographic areas for both restoration and protection benefits to the aggregate Scott River coho population. The categories are designated A (highest benefits) through E (lowest benefits) and ranks are grouped into those five categories separately for both restoration and protection benefits. Ranks are based on the average of individual rankings determined by the model separately for Neq spawner abundance, productivity, and the life history diversity index. The categorization of ranks is done within the model based on patterns of similarity in percentage change for each of the VSP metrics.

The tornado chart sorts the order of the geographic areas in the chart by the average combination of both restoration and protection benefits so that the projected highest ranked geographic area for overall benefits is shown at the top of the chart with benefits descending from there.

Scott River Coho salmon (normalized by reach length)

Relative Importance Of Geographic Areas For Protection and Restoration Measures

Geographic Area	Protection benefit Category	Protection benefit rank	Restoration benefit Category	Restoration benefit rank
French Cr lower	A	2	A	3
SR valley to tailings	A	1	A	8
SR valley to Etna Cr	B	7	A	4
SR valley to Kidder Cr	B	10	A	1
SR valley to forks	B	6	A	6
Shackleford Cr	B	12	A	1
Wolford Slough	A	2	A	11
Kidder lower-Big Slough	B	10	A	5
Mill-Emigrant Cr	B	8	A	10
East Fork MS lower	C	19	A	7
East Slough	C	16	A	11
Clark Cr	C	18	A	13
Miners Cr	B	8	C	26
South Fork MS	C	16	B	18
SR canyon MS upper	B	4	E	30
East Fork MS upper	C	22	A	13
SR canyon MS lower	B	5	E	31
Sugar Cr	B	12	C	24
Patterson Cr	C	21	B	16
French Cr upper	B	12	D	28
Moffett Cr lower	D	25	B	15
Oro Fino Cr	E	31	A	9
East Fork tribs	C	15	D	27
Sniktaw Cr	C	22	B	20
Crystal-Johnson Cr	D	24	B	19
Kidder Cr upper	D	27	B	17
East tribs to Ft Jones	D	25	C	22
South Fork tribs	C	20	E	29
Moffett Cr upper	D	27	C	23
Etna Cr	D	30	C	21
Wildcat Cr	D	27	C	24

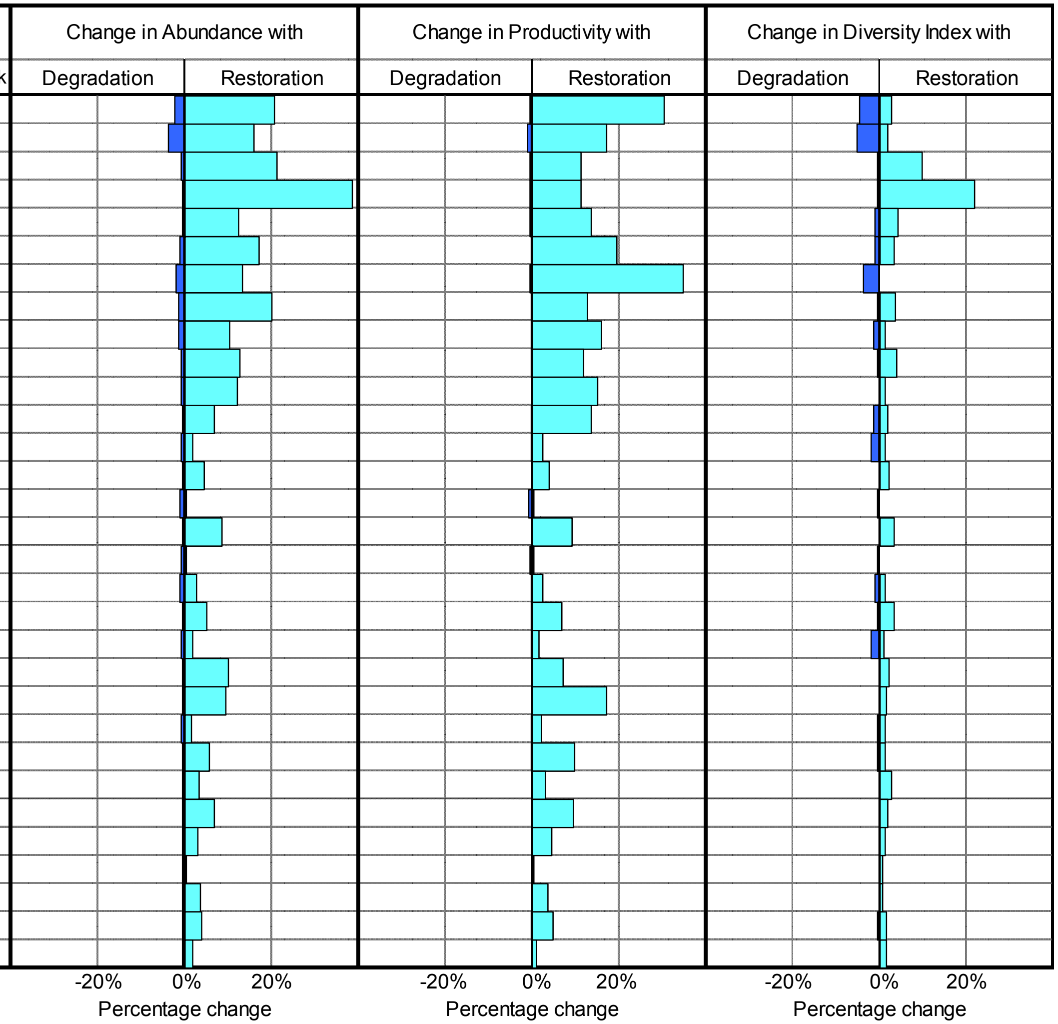

Figure 5-1. Relative importance of Geographic Areas for protection and restoration measures for Scott River coho salmon. Results are normalized by reach length. Percentage changes are shown for a standardized reach length of 1,000 m of stream channel.

Scott River Coho (not normalized by reach length)

Relative Importance Of Geographic Areas For Protection and Restoration Measures

Geographic Area	Protection benefit Category	Protection benefit rank	Restoration benefit Category	Restoration benefit rank
SR valley to tailings	A	1	A	5
SR valley to Etna Cr	B	6	A	3
SR valley to Kidder Cr	B	8	A	1
Kidder lower-Big Slough	B	9	A	2
SR valley to forks	B	6	B	7
French Cr lower	B	2	B	12
Shackleford Cr	B	12	B	6
Mill-Emigrant Cr	B	9	B	10
Wolford Slough	B	5	C	20
East Fork MS lower	C	18	B	9
East Fork MS upper	C	19	B	8
Moffett Cr lower	D	25	A	4
SR canyon MS lower	B	2	E	30
East Fork tribs	B	13	C	20
East Slough	C	17	C	16
SR canyon MS upper	B	4	E	29
Miners Cr	B	11	D	24
Patterson Cr	D	22	C	14
South Fork MS	C	16	C	20
Clark Cr	C	20	C	19
East tribs to Ft Jones	D	24	C	15
Kidder Cr upper	D	29	B	11
Sniktaw Cr	D	22	C	18
Etna Cr	D	25	C	16
French Cr upper	B	13	D	28
Oro Fino Cr	D	29	B	12
Sugar Cr	C	15	D	26
Crystal-Johnson Cr	D	21	D	25
Moffett Cr upper	D	25	D	23
Wildcat Cr	D	29	D	27
South Fork tribs	D	28	E	31

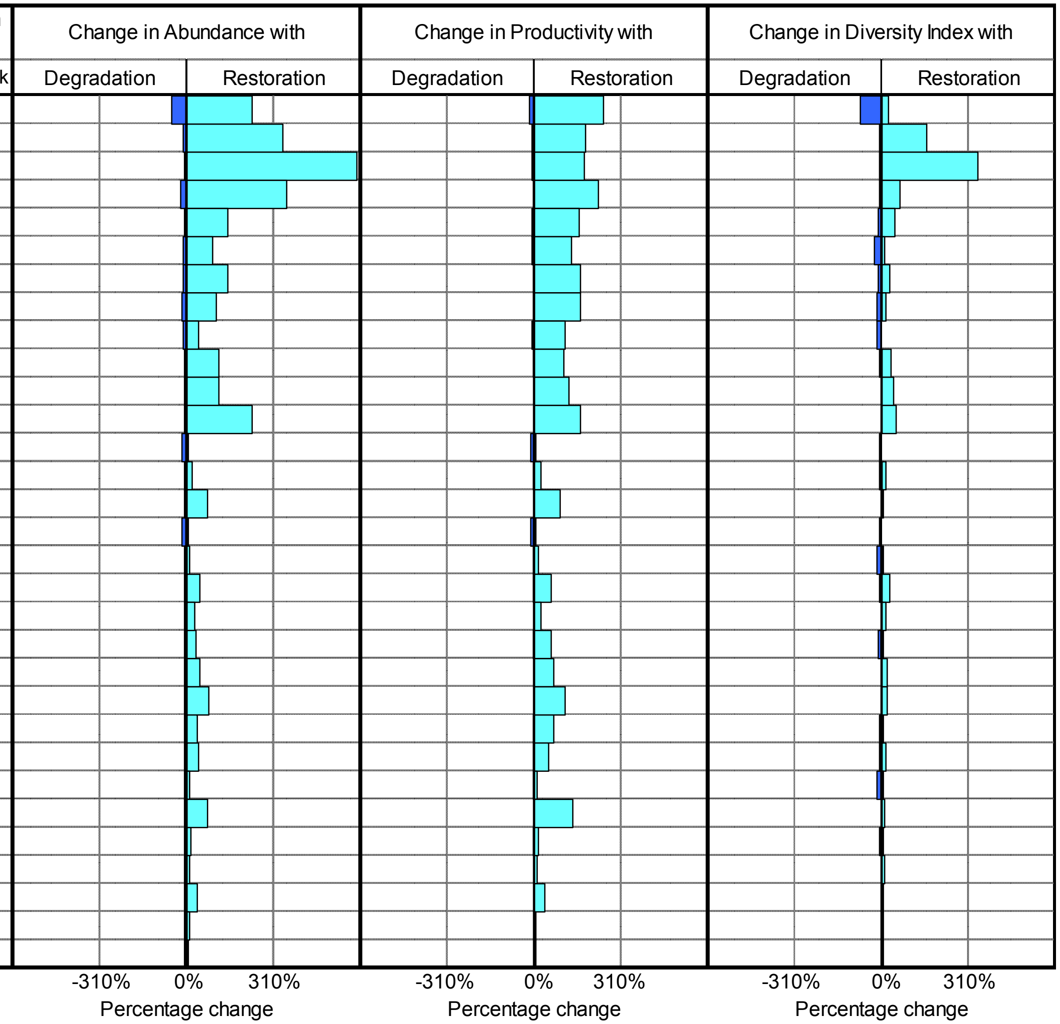

Figure 5-2. Relative importance of Geographic Areas for protection and restoration measures for Scott River coho salmon. Results are NOT normalized by reach length. Percentage changes are shown assuming the entire Geographic Area is either fully degraded or fully restored.

Of the 31 geographic areas delineated in the subbasin relevant to coho salmon, the geographic area identified to have the highest potential for restoration in combination with protection benefits for coho salmon was the mainstem Scott River between Etna Creek and the tailings reach (Figure 5-2). This result is not normalized for reach length so the benefit is projected to be the largest among all geographic areas to the aggregate coho population in the subbasin. When normalizing for reach length, the highest ranked geographic area was projected to be lower French Creek (between the mouth of French Creek and extending upstream to the mouth of Miner's Creek) (Figure 5-1). Using results normalized for reach length, the mainstem Scott River between Etna Creek and the tailings dropped to the second spot behind lower French Creek.

The consumer report style graphics in Figures 5-3 and 5-4 identify the relative contribution of different habitat survival factors to the decline of coho salmon performance associated within each geographic area. The geographic areas listed in these charts are not ordered by ranks as they were in Figures 5-1 and 5-2; here they are ordered more or less from north (at the top) to south. The five groupings (A to E) of restoration and protection benefits shown in Figure 5-1 and 5-2 are displayed in consumer report style to facilitate recognition of the patterns of results exhibited within the subbasin. The relative contribution of each habitat survival factor is illustrated by the size of the ovals displayed.

Results for all sixteen survival factors that are analyzed by the model are displayed in the figures. All of the factors listed in the figures except the one labeled "Habitat quantity" directly affect the productivity parameter for the aggregate population modeled.[14] Two matters related to streamflow should be noted. The first is that the factor labeled "Flow characteristics" addresses aspects of streamflow that affect productivity (or density-independent survival)—and not habitat quantity. The second matter of note is that the factor labeled "Habitat quantity" is a direct result of how much streamflow exists in the streams and its effect on habitat quantity used by coho salmon. (The reader should note that the size of the ovals in both Figures 5-3 and 5-4 are the same as these results are not affected by normalization on reach length.)

[14] / Habitat quantity affects habitat capacity of the population and not productivity (intrinsic).

Scott River Coho salmon (normalized by reach length)
Protection and Restoration Strategic Priority Summary

Geographic area priority			Attribute class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow characteristics	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Habitat quantity
SR canyon MS lower	B								C									
SR canyon MS upper	B								C									
SR valley to Kidder Cr	B	A	C				C		B						C			A
East tribs to Ft Jones		C	C				B	C	B	C					C	C		B
Sniktaw Cr	C	B	C				C		B						C			B
Shackleford Cr	B	A					C		A						C			B
Mill-Emigrant Cr	B	A					C		B						C			B
Oro Fino Cr		A	C				B	C	B	C					C			A
Moffett Cr lower		B	C				B	C	B						C			B
Moffett Cr upper		C					C		A						C			B
Kidder lower-Big Slough	B	A	C				C		B						C	C		B
Patterson Cr	C	B					C		A						C			B
Crystal-Johnson Cr		B	C				B		B						C	C		B
Kidder Cr upper		B	C				C		A						C			B
SR valley to Etna Cr	B	A	C				C		B						B			A
East Slough	C	A	C				C	C	B						B	C		A
Etna Cr		C					C		A						C			B
SR valley to tailings	A	A	C				C		B						C			A
Clark Cr	C	A					C	C	B									B
French Cr lower	A	A					C		B						C			B
Miners Cr	B	C					C		B						C			C
French Cr upper	B						C		B									C
Wolford Slough	A	A	C				C	C	C						C			A
SR valley to forks	B	A	C				B	C	A									B
Sugar Cr	B	C					C		B						C			C
Wildcat Cr		C	C				B	C	A						C			C
South Fork MS	C	B					C		A									B
South Fork tribs	C						C		B									
East Fork MS lower	C	A					B	C	A									B
East Fork tribs	C						C		B						C			B
East Fork MS upper	C	A	C				C	C	A									B

Key to strategic priority (corresponding Benefit Category letter also shown)

A	B	C	D & E
High	Medium	Low	Indirect or General

Figure 5-3. Relative importance of Geographic Areas for protection and restoration measures for Scott River coho salmon and relative importance habitat survival factors for restoration by Geographic Area. Results are normalized by reach length for Geographic Area priority. Habitat quantity and flow characteristics factors are both strongly affected by flow quantity.

Scott River Coho (not normalized by reach length)
Protection and Restoration Strategic Priority Summary

Geographic area priority			Attribute class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Habitat quantity
SR canyon MS lower	B								C									
SR canyon MS upper	B								C									
SR valley to Kidder Cr	B	A	C				C		B						C			A
Sniktaw Cr		C	C				C		B						C			B
Shackleford Cr	B	B					C		A						C			B
Mill-Emigrant Cr	B	B					C		B						C			B
East tribs to Ft Jones		C	C				B	C	B	C					C	C		B
Oro Fino Cr		B	C				B	C	B	C					C			A
Moffett Cr lower		A	C				B	C	B						C			B
Moffett Cr upper							C		A						C			B
Kidder lower-Big Slough	B	A	C				C		B						C	C		B
Patterson Cr		C					C		A						C			B
Kidder Cr upper		B	C				C		A						C			B
SR valley to Etna Cr	B	A	C				C		B						B			A
Crystal-Johnson Cr			C				B		B						C	C		B
East Slough	C	C	C				C	C	B						B	C		A
Etna Cr		C					C		A						C			B
SR valley to tailings	A	A	C				C		B						C			A
Clark Cr	C	C					C	C	B									B
French Cr lower	B	B					C		B						C			B
Miners Cr	B						C		B						C			C
French Cr upper	B						C		B									C
Wolford Slough	B	C	C				C	C	C						C			A
SR valley to forks	B	B	C				B	C	A									B
Sugar Cr	C						C		B						C			C
Wildcat Cr			C				B	C	A						C			C
South Fork MS	C	C					C		A									B
South Fork tribs							C		B									
East Fork MS lower	C	B					B	C	A									B
East Fork tribs	B	C					C		B						C			B
East Fork MS upper	C	B	C				C	C	A									B

Key to strategic priority (corresponding Benefit Category letter also shown)

A	B	C	D & E
High	Medium	Low	Indirect or General

Figure 5-4. Relative importance of Geographic Areas for protection and restoration measures for Scott River coho salmon and relative importance habitat survival factors for restoration by Geographic Area. Results are NOT normalized by reach length for Geographic Area priority. Habitat quantity and flow characteristics factors are both strongly affected by flow quantity.

Figures 5-3 and 5-4 show that the model projected that the four survival factors that have had the greatest effect on coho salmon performance in the subbasin are those labeled habitat diversity, habitat quantity, flow characteristics, and sediment load. The environmental attributes that compose these four survival factors for coho salmon are listed in Table 5-2 (see Appendix B for definitions of environmental attributes).

Table 5-2. Environmental attributes that affect the four major habitat survival factors affecting Scott River coho salmon. See Appendices A and B for definitions.

Habitat survival factor	Related EDT environmental attribute (includes mitigating attributes)
Habitat diversity	Gradient Confinement (natural) Confinement (artificial) Riparian function Side channel complexity Wood load
Habitat quantity	Wetted channel width (flow related) Habitat type composition
Flow characteristics	Flow - interannual variability in low flow Embeddedness Confinement (natural) Confinement (artificial) Habitat type - backwater pools Habitat type - beaver ponds Habitat type - primary pools Riparian function Wood load
Sediment load	Embeddedness Fine sediment Total suspended solids

Some explanation is needed as to why the temperature survival factor is not shown to be of greater importance in affecting population performance. At first glance, this seems puzzling. Two reasons explain the results. First, the historical temperature conditions during the summer were assumed to be relatively warm at many locations within the subbasin. While temperatures have been assumed to have increased at most locations, some groundwater remains present at many sites, such as near the confluences of the major tributaries, to provide sources of thermal refuge. And secondly, the life histories of the population as modeled have not been primarily affected by summer temperatures to the degree that they have been affected by other factors. However, it is important to recognize that temperature is still having an effect in the model, though not to the extent as other factors.

The reader should note that the model calculations that go into computing the survival factor metrics depicted in Figures 5-3 and 5-4 combine the effects for all affected life stages experienced within a geographic area.

5.2.2. Fall Chinook Salmon

The modeling results demonstrate a large loss in fall Chinook salmon performance between the historical and current baselines. The loss is reflected in each of the VSP metrics evaluated by the model and has occurred in each of the major population components. The modeling results are consistent with empirical data on average population abundance returning to Scott River with application of an average fishery exploitation rate (see Section 4.2.2).

The tornado charts in Figure 5-5 and 5-6 rank, and categorize the ranks, by the relative importance of the different geographic areas for both restoration and protection benefits to the aggregate Scott River coho population. The categories are designated A (highest benefits) through E (lowest benefits) and ranks are grouped into those five categories separately for both restoration and protection benefits. Ranks are based on the average of individual rankings determined by the model separately for Neq spawner abundance, productivity, and the life history diversity index. The categorization of ranks is done within the model based on patterns of similarity in percentage change for each of the VSP metrics.

The tornado chart sorts the order of the geographic areas in the chart by the average combination of both restoration and protection benefits so that the projected highest ranked geographic area for overall benefits is shown at the top of the chart with benefits descending from there.

Of the 14 geographic areas delineated in the subbasin relevant to fall Chinook salmon, the geographic area identified to have the highest potential for restoration in combination with protection benefits for fall Chinook salmon was the mainstem Scott River between its confluence with the Klamath River and Middle Creek (approximately RM 12.8) (Figure 5-6). This result is not normalized for reach length so the benefit is projected to be the largest among all geographic areas to the aggregate fall Chinook population in the subbasin. It is noteworthy that other geographic areas had a higher restoration benefit to overall Neq abundance but the lower Scott River mainstem geographic area had the highest protection benefit of all areas. The second highest ranked geographic area for overall benefits was the area located just upstream – the mainstem Scott River area between Middle Creek and the upstream end of the canyon area (approximately RM 22.6). This area also ranked high for protection benefits.

When normalizing for reach length, the highest ranked geographic area remained the same as for the non-normalized results – the mainstem Scott River between its confluence with the Klamath River and Middle Creek (Figure 5-5). The second and third highest ranked areas were Shackleford Creek and the mainstem Scott River between the start of the valley and Kidder Creek. These areas had relatively low protection benefits but high restoration benefits.

Scott River Fall Chinook (normalized by reach length)

Relative Importance Of Geographic Areas For Protection and Restoration Measures

Geographic Area	Protection benefit Category/rank		Restoration benefit Category/rank	
SR canyon MS lower	A	1	A	6
Shackleford Cr	B	7	A	1
SR valley to Kidder Cr	B	5	A	3
SR canyon MS upper	A	2	B	8
SR valley to tailings	B	6	A	5
SR valley to Etna Cr	C	10	A	2
Kidder lower-Big Slough	B	6	B	7
Etna Cr	B	7	B	9
Moffett Cr lower	D	13	A	3
SR canyon tribs	A	3	D	13
Patterson Cr	C	10	B	9
Mill-Emigrant Cr	B	8	C	12
Kidder Cr upper	C	12	C	11
Sniktaw Cr	D	14	D	13

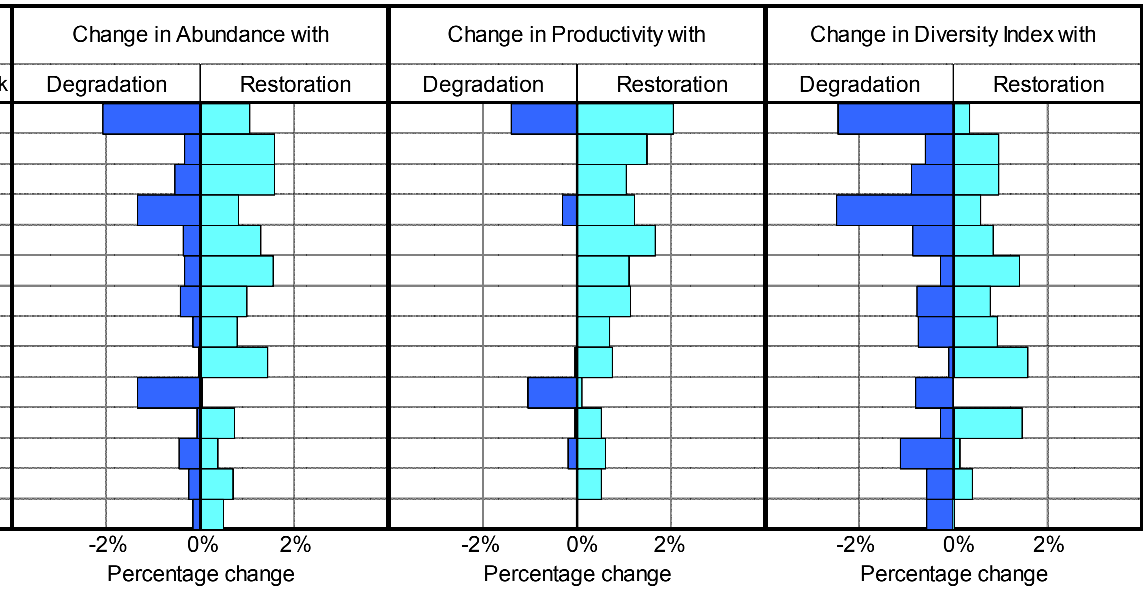

Figure 5-5. Relative importance of Geographic Areas for protection and restoration measures for Scott River fall Chinook salmon. Results are normalized by reach length. Percentage changes are shown for a standardized reach length of 1,000 m of stream channel.

Scott River Fall Chinook (not normalized by reach length)

Relative Importance Of Geographic Areas For Protection and Restoration Measures

Geographic Area	Protection benefit Category/rank		Restoration benefit Category/rank	
SR canyon MS lower	A	1	A	3
SR canyon MS upper	A	2	B	4
SR valley to Kidder Cr	B	5	A	2
SR valley to Etna Cr	B	7	A	1
Kidder lower-Big Slough	B	6	B	6
Shackleford Cr	B	7	B	7
SR valley to tailings	B	7	B	8
Moffett Cr lower	D	11	B	5
SR canyon tribs	B	3	D	13
Mill-Emigrant Cr	B	8	C	11
Etna Cr	D	10	C	10
Kidder Cr upper	D	12	C	9
Patterson Cr	D	13	C	12
Sniktaw Cr	D	14	D	14

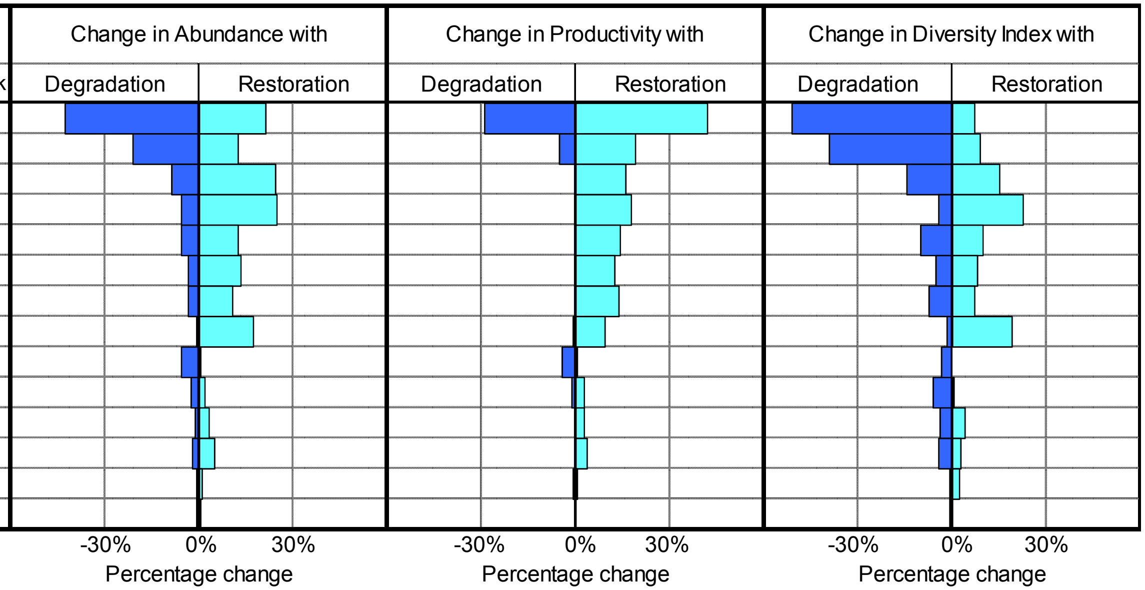

Figure 5-6. Relative importance of Geographic Areas for protection and restoration measures for Scott River fall Chinook salmon. Results are NOT normalized by reach length. Percentage changes are shown assuming the entire Geographic Area is either fully degraded or fully restored.

Results of the analysis of habitat survival factors are displayed in Figures 5-7 and 5-8. These figures identify the relative contribution of different habitat survival factors to the decline of fall Chinook salmon performance associated with each geographic area. The geographic areas listed in these charts are not ordered by ranks as they were in Figure 5-5 and 5-6; here they are ordered more or less from north (at the top) to south. The five groupings (A to E) of restoration and protection benefits shown in Figure 5-5 and 5-6 are displayed in Figure 5-7 and 5-8 in consumer report style to facilitate recognition of the patterns of results exhibited within the subbasin. The relative contribution of each habitat survival factor is illustrated by the size of the ovals displayed.

Results for all sixteen survival factors that are analyzed by the model are displayed in the figures. All of the factors listed in the figures except the one labeled "Habitat quantity" directly affect the productivity parameter for the aggregate population modeled.[15] Two matters related to streamflow should be noted. The first is that the factor labeled "Flow characteristics" addresses aspects of streamflow that affect productivity (or density-independent survival)—and not habitat quantity. The second matter of note is that the factor labeled "Habitat quantity" is a direct result of how much streamflow exists in the streams and its effect on habitat quantity used by fall Chinook salmon. (The reader should note that the size of the ovals in both Figures 5-7 and 5-8 are the same as these results are not affected by normalization on reach length.)

Figures 5-7 and 5-8 show that the model projected that the four survival factors that have had the greatest effect on fall Chinook salmon performance in the subbasin are those labeled habitat diversity, habitat quantity, flow characteristics, and sediment load. The environmental attributes that compose these four survival factors most relevant to fall Chinook salmon are the same as those that were listed for coho salmon (Table 5-2).

The reader should note that the model calculations that go into computing the survival factor metrics depicted in Figures 5-7 and 5-8 combine the effects for all affected life stages experienced within a geographic area.

---

[15] / Habitat quantity affects habitat capacity of the population and not productivity (intrinsic).

Scott River Fall Chinook (normalized by reach length)
Protection and Restoration Strategic Priority Summary

Geographic area priority			Attribute class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	*Channel stability*	*Chemicals*	*Competition (w/ hatch)*	*Competition (other sp)*	*Flow*	*Food*	*Habitat diversity*	*Harassment/poaching*	*Obstructions*	*Oxygen*	*Pathogens*	*Predation*	*Sediment load*	*Temperature*	*Withdrawals*	*Key habitat quantity*
SR canyon MS lower	◯	◯					•		●						•			●
SR canyon MS upper	◯	○					•		●						•			●
SR canyon tribs	◯								●									
SR valley to Kidder Cr	○	◯	•				●		●						•			●
Sniktaw Cr			•				●	•	●									●
Shackleford Cr	○	◯					●		⬤						•			●
Mill-Emigrant Cr	○	∘					•		●									●
Moffett Cr lower		◯	•				●	•	⬤						•			●
Kidder lower-Big Slough	○	○	•				•		●						•			●
Patterson Cr	∘	○	•				●		⬤						•			●
Kidder Cr upper	∘	∘	•				●		●						•			•
SR valley to Etna Cr	∘	◯	•				●		●						●			●
Etna Cr	○	○	•				●	•	⬤	•								●
SR valley to tailings	○	◯	•				●		●						•			●

Key to strategic priority (corresponding Benefit Category letter also shown)

A		B		C		D & E	
◯ / ⬤	High	○ / ●	Medium	∘ / •	Low	(blank)	Indirect or General

Figure 5-7. Relative importance of Geographic Areas for protection and restoration measures for Scott River fall Chinook salmon and relative importance habitat survival factors for restoration by Geographic Area. Results are normalized by reach length for Geographic Area priority. Habitat quantity and flow characteristics factors are both strongly affected by flow quantity.

Scott River Fall Chinook (not normalized by reach length)
Protection and Restoration Strategic Priority Summary

Geographic area priority			Attribute class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	*Channel stability*	*Chemicals*	*Competition (w/ hatch)*	*Competition (other sp)*	*Flow*	*Food*	*Habitat diversity*	*Harassment/poaching*	*Obstructions*	*Oxygen*	*Pathogens*	*Predation*	*Sediment load*	*Temperature*	*Withdrawals*	*Habitat quantity*
SR canyon MS lower	◯	◯					•		●						•			●
SR canyon MS upper	◯	○					•		●						•			●
SR canyon tribs	○								●									
SR valley to Kidder Cr	○	◯	•				●		●						•			●
Sniktaw Cr			•				●	•	●									●
Shackleford Cr	○	○					●		⬤						•			●
Mill-Emigrant Cr	○	∘					•		●									●
Moffett Cr lower		○	•				●	•	⬤						•			●
Kidder lower-Big Slough	○	○	•				•		●						•			●
Patterson Cr		∘	•				●		⬤						•			●
Kidder Cr upper		∘	•				●		●						•			•
SR valley to Etna Cr	○	◯	•				●		●						●			●
Etna Cr		∘	•				●	•	⬤	•								●
SR valley to tailings	○	○	•				●		●						•			●

Key to strategic priority (corresponding Benefit Category letter also shown)

A		B		C		D & E	
◯ / ⬤	High	○ / ●	Medium	∘ / •	Low	(blank)	Indirect or General

Figure 5-8. Relative importance of Geographic Areas for protection and restoration measures for Scott River fall Chinook salmon and relative importance habitat survival factors for restoration by Geographic Area. Results are NOT normalized by reach length for Geographic Area priority. Habitat quantity and flow characteristics factors are both strongly affected by flow quantity.

5.2.3. Spring Chinook Salmon

The modeling results demonstrate an enormous loss in spring Chinook salmon performance between the historical and current baselines. The loss is reflected in each of the VSP metrics evaluated by the model and has occurred in each of the major population components. The modeling results are consistent with empirical data on population abundance – the population was extirpated in the early 1970s.

The tornado charts in Figure 5-9 and 5-10 rank, and categorize the ranks, by the relative importance of the different geographic areas for both restoration and protection benefits to the aggregate Scott River spring Chinook population. The categories are designated A (highest benefits) through E (lowest benefits) and ranks are grouped into those five categories separately for both restoration and protection benefits. Ranks are based on the average of individual rankings determined by the model separately for Neq spawner abundance, productivity, and the life history diversity index. The categorization of ranks is done within the model based on patterns of similarity in percentage change for each of the VSP metrics.

The tornado chart sorts the order of the geographic areas in the chart by the average combination of both restoration and protection benefits so that the projected highest ranked geographic area for overall benefits is shown at the top of the chart with benefits descending from there.

Of the 15 geographic areas delineated in the subbasin relevant to spring Chinook salmon, the geographic area identified to have the highest potential for restoration in combination with protection benefits for spring Chinook salmon was the mainstem Scott River between Etna Creek (approximately RM 42.5) and the start of the tailings reach at approximately RM 51.5 (Figure 5-10). This geographic area had high benefits for both protection and restoration. This result is not normalized for reach length so the benefit is projected to be the largest among all geographic areas to the aggregate spring Chinook population in the subbasin. The second highest ranked geographic area for overall benefits was the mainstem South Fork area. Restoration benefits in this area were modest but the area provided higher protection benefits than most other geographic areas.

When normalizing for reach length, the three highest ranked areas for benefits were lower French Creek, the mainstem mainstem Scott River between Etna Creek and the start of the tailings reach, and Sugar Creek (Figure 5-9) in order of benefits.

Results of the analysis of habitat survival factors are displayed in Figures 5-11 and 5-12. These figures identify the relative contribution of different habitat survival factors to the decline of spring Chinook salmon performance associated with each geographic area. The geographic areas listed in these charts are not ordered by ranks as they were in Figures 5-9 and 5-10; here they are ordered more or less from north (at the top) to south. The five groupings (A to E) of restoration and protection benefits shown in Figures 5-9 and 5-10 are displayed in Figures 5-11 and 5-12 in consumer report style to facilitate recognition of the patterns of results exhibited within the subbasin. The relative contribution of each habitat survival factor is illustrated by the size of the ovals displayed.

Scott River Spring Chinook (normalized for reach length)

Relative Importance Of Geographic Areas For Protection and Restoration Measures

Geographic Area	Protection benefit Category/rank		Restoration benefit Category/rank	
French Cr lower	B	5	A	2
SR valley to tailings	B	4	A	3
Sugar Cr	A	1	A	6
East Fork MS lower	C	6	A	3
South Fork MS	A	2	B	8
East Fork tribs	B	3	C	10
SR valley to forks	E	14	A	1
Etna Cr	E	15	A	3
East Fork MS upper	D	10	B	9
Wolford Slough	D	13	A	6
South Fork tribs	D	8	D	12
SR canyon MS upper	C	6	D	15
SR valley to Etna Cr	D	11	D	11
SR canyon MS lower	D	9	D	14
SR valley to Kidder Cr	D	12	D	12

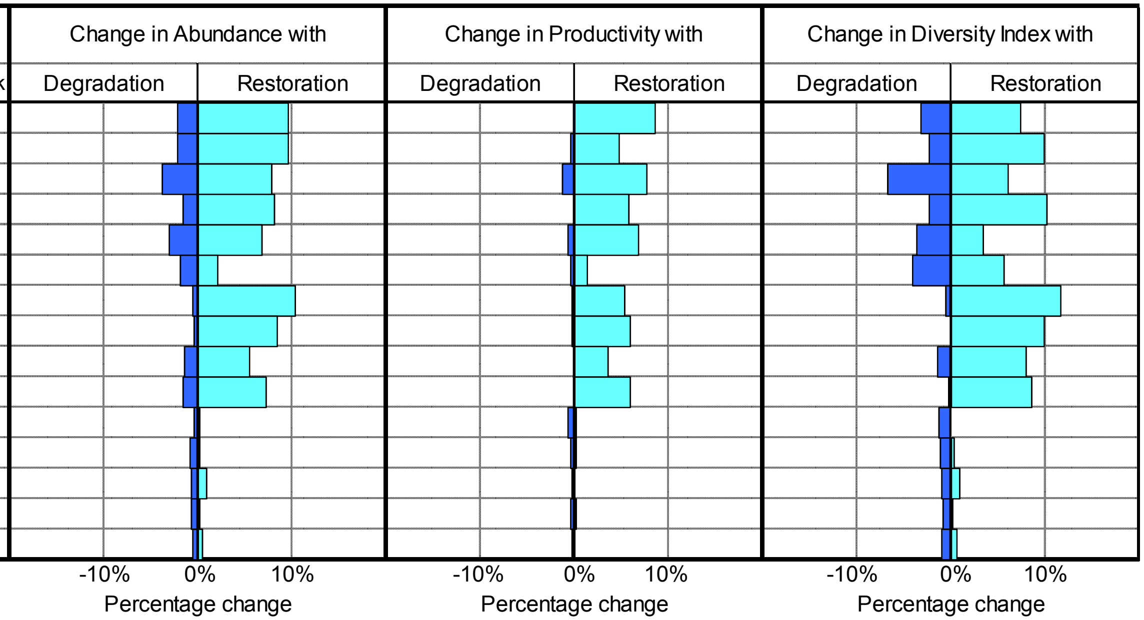

Figure 5-9. Relative importance of Geographic Areas for protection and restoration measures for Scott River spring Chinook salmon. Results are normalized by reach length. Percentage changes are shown for a standardized reach length of 1,000 m of stream channel.

Scott River Spring Chinook (not normalized for reach length)

Relative Importance Of Geographic Areas For Protection and Restoration Measures

Geographic Area	Protection benefit Category/rank		Restoration benefit Category/rank	
SR valley to tailings	A	2	A	1
South Fork MS	A	2	C	6
East Fork MS lower	B	5	B	4
East Fork MS upper	B	7	B	3
SR valley to forks	C	11	A	2
French Cr lower	B	10	C	6
SR canyon MS lower	B	3	D	13
Sugar Cr	B	7	C	9
SR canyon MS upper	B	4	D	13
SR valley to Etna Cr	B	7	C	10
SR valley to Kidder Cr	B	9	D	12
Wolford Slough	C	13	C	8
Etna Cr	D	15	C	7
East Fork tribs	C	12	D	11
South Fork tribs	D	14	E	15

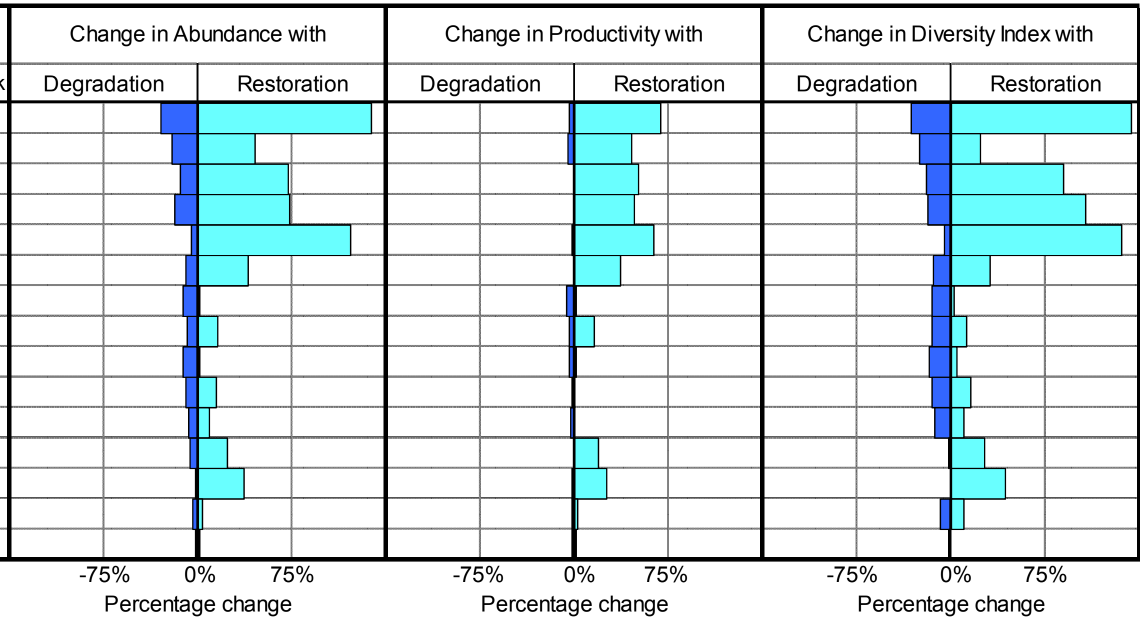

Figure 5-10. Relative importance of Geographic Areas for protection and restoration measures for Scott River spring Chinook salmon. Results are NOT normalized by reach length. Percentage changes are shown assuming the entire Geographic Area is either fully degraded or fully restored.

Scott River Spring Chinook (normalized for reach length)
Protection and Restoration Strategic Priority Summary

Geographic area priority			Attribute class priority for restoration															
Geographic area	Protection benefit	Restoration benefit	Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
SR canyon MS lower									•									•
SR canyon MS upper	∘						•		●									•
SR valley to Kidder Cr			•				•		●									●
SR valley to Etna Cr			•				•		●									●
Etna Cr		◯	•				●	•	●	•								●
SR valley to tailings	○	◯	•				•		•						•			●
French Cr lower	○	◯					•		●						•			●
Wolford Slough		◯	•				•	•	•						•	•		⬤
SR valley to forks		◯	•				●	•	⬤									●
Sugar Cr	◯	◯					•		●						•			•
South Fork MS	◯	○	•				•		●									•
South Fork tribs			•				•		●									
East Fork MS lower	∘	◯	•				●	•	⬤									•
East Fork tribs	○	∘					•		●						•			
East Fork MS upper		○	•				•	•	●									•

Key to strategic priority (corresponding Benefit Category letter also shown)

A		B		C		D & E	
◯ / ⬤	High	○ / ●	Medium	∘ / •	Low	(blank)	Indirect or General

Figure 5-11. Relative importance of Geographic Areas for protection and restoration measures for Scott River spring Chinook salmon and relative importance habitat survival factors for restoration by Geographic Area. Results are normalized by reach length for Geographic Area priority. Habitat quantity and flow characteristics factors are both strongly affected by flow quantity.

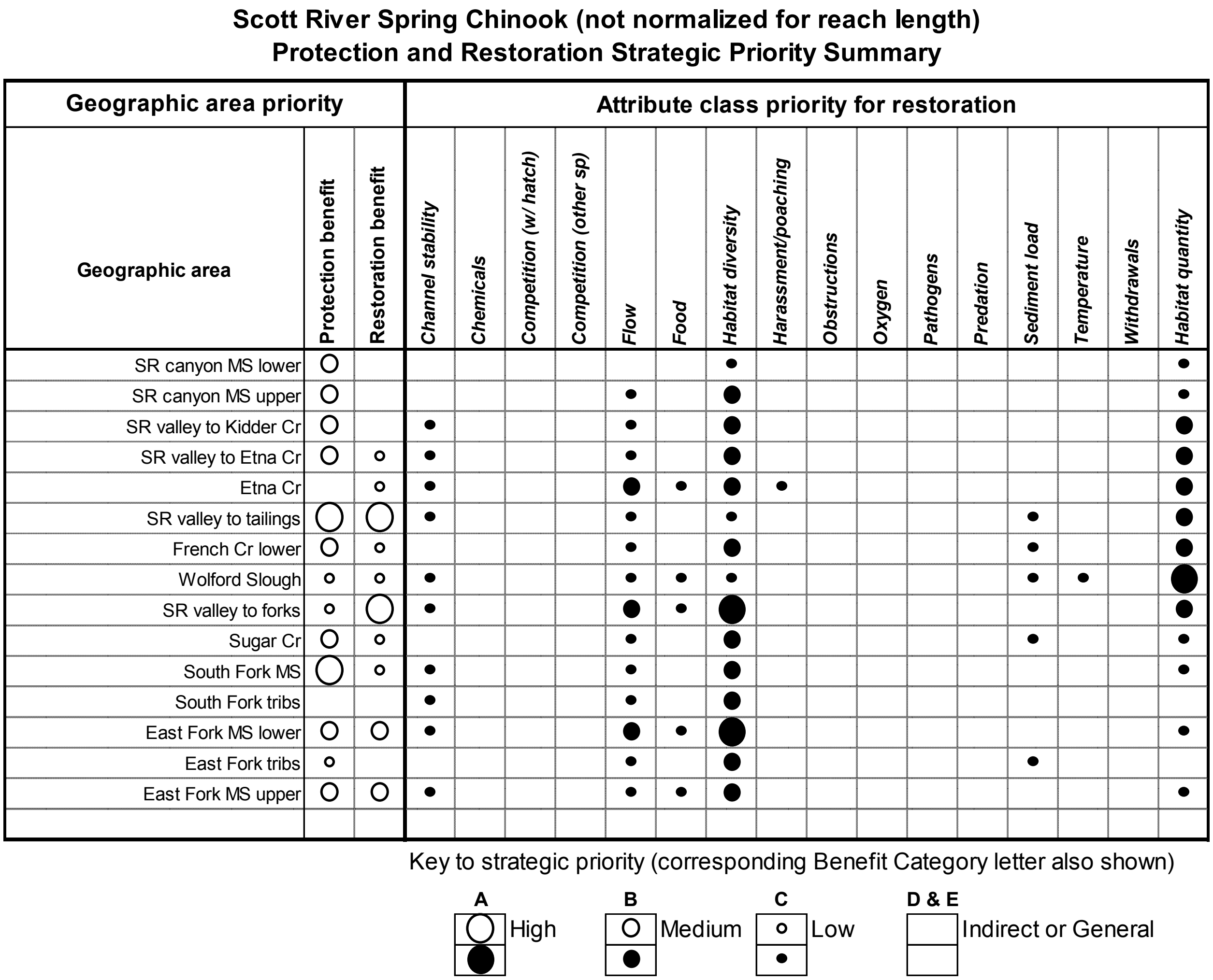

Figure 5-12. Relative importance of Geographic Areas for protection and restoration measures for Scott River spring Chinook salmon and relative importance habitat survival factors for restoration by Geographic Area. Results are NOT normalized by reach length for Geographic Area priority. Habitat quantity and flow characteristics factors are both strongly affected by flow quantity.

Results for all sixteen survival factors that are analyzed by the model are displayed in the figures. All of the factors listed in the figures except the one labeled "Habitat quantity" directly affect the productivity parameter for the aggregate population modeled.[16] Two matters related to streamflow should be noted. The first is that the factor labeled "Flow characteristics" addresses aspects of streamflow that affect productivity (or density-independent survival)—and not habitat quantity. The second matter of note is that the factor labeled "Habitat quantity" is a direct result of how much streamflow exists in the streams and its effect on habitat quantity used by spring Chinook salmon. (The reader should note that the size of the ovals in both Figures 5-11 and 5-12 are the same as these results are not affected by normalization on reach length.)

---

[16] / Habitat quantity affects habitat capacity of the population and not productivity (intrinsic).

Figures 5-11 and 5-12 show that the model projected that the three survival factors that have had the greatest effect on spring Chinook salmon performance in the subbasin are those labeled habitat diversity, habitat quantity, and flow characteristics. The environmental attributes that compose these three survival factors most relevant to spring Chinook salmon are the same as those that were listed for coho salmon (see Table 5-2).

Some explanation is needed as to why the temperature survival factor is not shown to be of greater importance in affecting population performance. As noted for coho, this seems puzzling. Two reasons explain the results. First, the historical temperature conditions during the summer were assumed to be relatively warm at many locations within the subbasin. While temperatures have been assumed to have increased at most locations, some groundwater remains present at many sites, such as near the confluences of the major tributaries, to provide sources of thermal refuge. And secondly and most important for spring Chinook, the life histories of the population as modeled have not been primarily affected by summer temperatures to the degree that they have been affected by other factors. However, it is important to recognize that temperature is still having an effect in the model, though not to the extent as other factors.

The reader should note that the model calculations that go into computing the survival factor metrics depicted in Figures 5-11 and 5-12 combine the effects for all affected life stages experienced within a geographic area.

6. Restoration Scenario Analysis

Four generalized restoration scenarios were developed for analysis using the EDT model. The scenarios were based on the results of the diagnosis and considered reduction of groundwater pumping, riparian restoration, floodplain channels restoration, and a combination of those three categories of actions. I note that none of the restoration scenarios considers potential restoration measures in the mainstem Klamath River. No consideration was given to possible effects of dam removal within the Klamath River.

6.1. Scenario Development

I developed four distinct restoration scenarios for modeling to compare population performance for the three salmon populations under a wide range of restoration approaches. These scenarios are not meant to be realistic proposals for restoration—they are hypothetical "what ifs." They were developed to help inform about the kinds, magnitude, locations, and intensities of restoration actions that would be needed to bring about a substantial improvement in the performance of the three populations. A meaningful and effective restoration program would need to include elements of these hypothetical scenarios as well as other elements.

An actual restoration plan would strategically target specific areas in conjunction with opportunities made available for restoration.

The four scenarios were developed around four different themes (Table 6-1). Two scenarios are directed within a limited geographic space within the subbasin, while the other two covered essentially the entire stream system being modeled within EDT. The two geographically limited scenarios encompass the area where groundwater pumping largely occurs in the valley (Papadopulos & Associates 2012). The four scenarios are described below.

Table 6-1. Four hypothetical restoration scenarios modeled to inform restoration considerations.

Scenario	Areas affected directly	Description	EDT attributes affected
Restore prepumping flow	All reaches directly affected by major groundwater pumping	Restore surface water flows to levels prior to the onset of major groundwater pumping that began in the early to mid-1970s	• Wetted channel width • FlowLow • Temperature variation
Restore riparian	Entire subbasin	Restore all riparian zone conditions to historical characteristics (no changes are assumed for floodplain channels or in-stream channels)	• Riparian function • Temperature variation • Temperature maximum • Benthos
Restore floodplains	Entire subbasin	Restore all floodplain channel conditions to historical characteristics (no changes are assumed for riparian vegetation or in-stream channels)	• Seasonally inundated floodplains • Side channels • Floodplain ponds • Reach length • Temperature variation • Benthos
Combination	All reaches directly affected by major groundwater pumping	Restores a combination of conditions from scenarios above: • Restore ½ of surface flow lost by groundwater pumping • Restore ½ of riparian zone conditions to reaches directly affected by groundwater pumping • Restore ½ of floodplain channel conditions to reaches directly affected by groundwater pumping • Restore ½ of historical wood load to reaches directly affected by groundwater pumping • Restore in-stream channel habitat types to the average of historical and conditions	• Wetted channel width • FlowLow • Temperature variation • Temperature maximum • Seasonally inundated floodplains • Side channels • Floodplain ponds • Reach length • Wood load • Macro habitat type composition • Benthos

1. **Prepumping Flow Restoration Scenario**. This scenario is directed at assessing the effects of restoring surface flows to quantities that existed prior to the advent of significant groundwater pumping that ramped up in the early to mid-1970s. Stream reaches affected by this scenario are those where surface flows would be expected to increase if groundwater pumping were to cease. No other restoration actions are included in this scenario. The main assumptions for this scenario are that surface flows would be restored to levels that existed in the early 1970s and

that some amount of temperature spatial variation would be restored by an increase in groundwater returning to the streams. EDT environmental attributes assumed to be affected by this scenario are listed in Table 6-1.

2. **Riparian Restoration Scenario**. This scenario focuses solely on restoring the riparian vegetation within the riparian zone of the river system. The historical riparian function assumed within the model, excluding the accumulation of wood load and other related aspects of in-channel and off-channel features incorporated into the model, would be fully restored to all stream reaches in the model. EDT environmental attributes assumed to be affected by this scenario are listed in Table 6-1.
3. **Floodplain Channels Restoration Scenario**. This scenario focuses solely on restoring the historical floodplain channels of the entirety of Scott River system. These channels are assumed to include all secondary channels (i.e., side channels), floodplain ponds that are either continuously connected or seasonally connected to the mainstem stream channel (these include beaver pond complexes), and seasonally inundated floodplain areas and wetlands. No changes are assumed to occur to the mainstem stream channels. EDT environmental attributes assumed to be affected by this scenario are listed in Table 6-1.
4. **Combination Restoration Scenario**. This scenario is a combination of the other three scenarios and is limited to the geographic area where significant groundwater pumping occurs. This scenario has the same geographic coverage as Scenario 1 (Prepumping). In addition to restoring a part of the groundwater being taken by pumping, the scenario would combine some riparian restoration, floodplain channel restoration, and in-channel features that could be expected to occur with riparian and floodplain restoration. Within the geographic area of focus, the intensity of restoration treatment in this case would be reduced to half of those levels applied in Scenarios 1, 2, and 3. Groundwater contribution to surface flows would be restored to ½ of the amounts restored in Scenario 1. Riparian restoration would be ½ of the amounts applied in Scenario 2 within the area of treatment. Floodplain channel restoration would be ½ of the amounts applied in Scenario 3 within the area of treatment. In addition, this scenario assumes that other aspects of riparian and floodplain restoration would result (not assumed in Scenarios 2 and 3), i.e., in-channel wood loads would increase and habitat types would be partially restored. Wood loads and habitat types were assumed to be restored to levels midway between current and historical conditions. However, no changes were assumed to occur to what EDT calls artificial channel confinement, which includes incision, channelization (with the exception that some reach length would be restored), and diking and bank hardening. EDT environmental attributes assumed to be affected by this scenario are listed in Table 6-1.

To parameterize model inputs for the restoration scenarios, the values of the EDT environmental attributes listed in Table 6-1 were adjusted from the current baseline for all relevant stream reaches to correspond to the scenario descriptions. I followed procedures normally applied in these kinds of EDT assessments used elsewhere, e.g., Puget Sound rivers (Thompson et al. 2009), Hood Canal streams (Lestelle et al. 2014), mid-Columbia Oregon rivers (Carmichael and Taylor 2009), northeast Oregon rivers (NMFS 2014), and Chehalis River (ASRPSC 2019).

Wetted stream widths for the Prepumping scenario were keyed to the assumption that streamflow at the USGS gauging station just downstream of the valley would be restored to the average September flow that existed prior to the mid-1970s (Table 6-2). Streamflow upstream of that point was reconstructed through the EDT stream reach system based on flow patterns and changes in flow at various points along the stream system used to characterize the current baseline. Wetted channel widths for the Combination scenario were parameterized in the same way but reducing the amount of restored flow from the Prepumping scenario by half. Wetted main channel widths for the Riparian and Floodplain scenarios remained unchanged from those for the current baseline.

Table 6-2. Average September flow and wetted channel width applied in four modeling scenarios.

Scenario	Ave September cfs	Wetted channel width ft
Historical baseline	137	85
Current baseline	24	40
Prepumping	62	60
Combination	43	50

6.2. Scenario Results

6.2.1. Coho Salmon

Scenario analysis results for coho salmon are summarized for the aggregate total population and the four major geomorphic areas of the subbasin distinguished in the analysis (Table 6-3; Figure 6-1). Results are compared to the current baseline for Neq abundance, productivity, and life history diversity. Figure 6-2 compares the S-P production curves for the aggregate population for the four restoration scenarios and the current baseline. Figure 6-3 displays population performance metrics among the scenarios for the major geomorphic areas.

Table 6-3. Modeling results for the four restoration scenarios compared to the current baseline for coho salmon.

Population component	Scenario					Percent change from current			
	Current	Prepump	Riparian	Fldplain	Combo	Prepump	Riparian	Fldplain	Combo
					Neq abundance				
All	415	482	1,394	1,896	2,880	16.0%	235.5%	356.3%	593.3%
Forks	43	43	196	204	111	1.0%	355.8%	374.8%	157.2%
Upper valley	193	239	418	549	879	23.5%	116.4%	184.1%	354.9%
Lower valley	130	146	692	1,081	1,792	11.9%	431.4%	730.4%	1276.8%
Canyon	21	21	21	21	21	0.0%	0.0%	0.0%	0.0%
					Productivity				
All	2.7	2.7	3.3	3.2	4.6	2.1%	23.9%	18.3%	73.5%
Forks	2.1	2.1	2.6	2.7	2.1	0.1%	25.6%	28.5%	1.7%
Upper valley	2.8	2.8	4.1	3.5	5.4	1.8%	50.2%	25.9%	96.7%
Lower valley	2.1	2.1	2.7	2.9	4.2	0.0%	26.2%	36.2%	94.5%
Canyon	1.8	1.8	1.8	1.8	1.8	0.0%	0.0%	0.0%	0.0%
					Life history diversity index				
All	5.0%	5.0%	52.2%	49.5%	47.9%	0.0%	953.5%	899.0%	868.2%
Forks	0.9%	0.9%	33.0%	32.3%	5.9%	0.0%	3416.7%	3350.0%	533.3%
Upper valley	14.0%	14.0%	69.0%	78.2%	70.5%	0.0%	392.1%	457.9%	403.0%
Lower valley	1.3%	1.3%	48.8%	39.1%	48.1%	0.0%	3714.3%	2957.1%	3664.3%
Canyon	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%

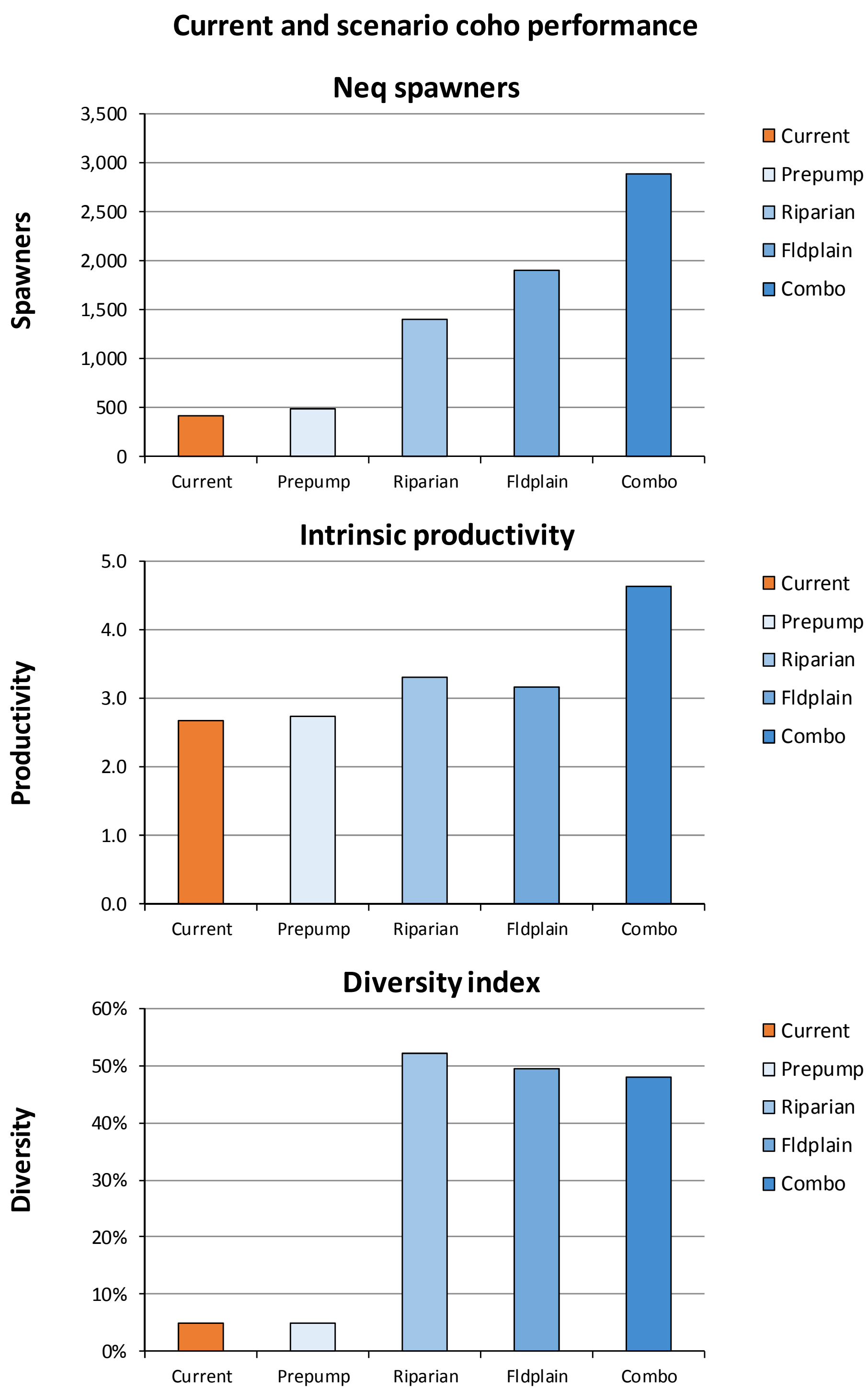

Figure 6-1. Modeling results for the four restoration scenarios compared to the current baseline for coho salmon.

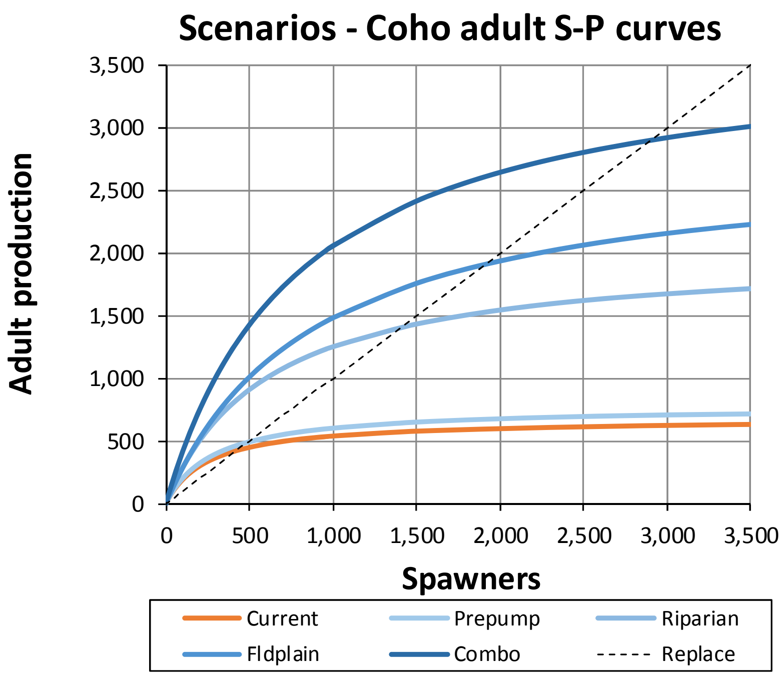

Figure 6-2. Spawner-production curves for the four restoration scenarios compared to the current baseline S-P relationship for coho salmon measured at the spawner life stage derived from EDT modeling.

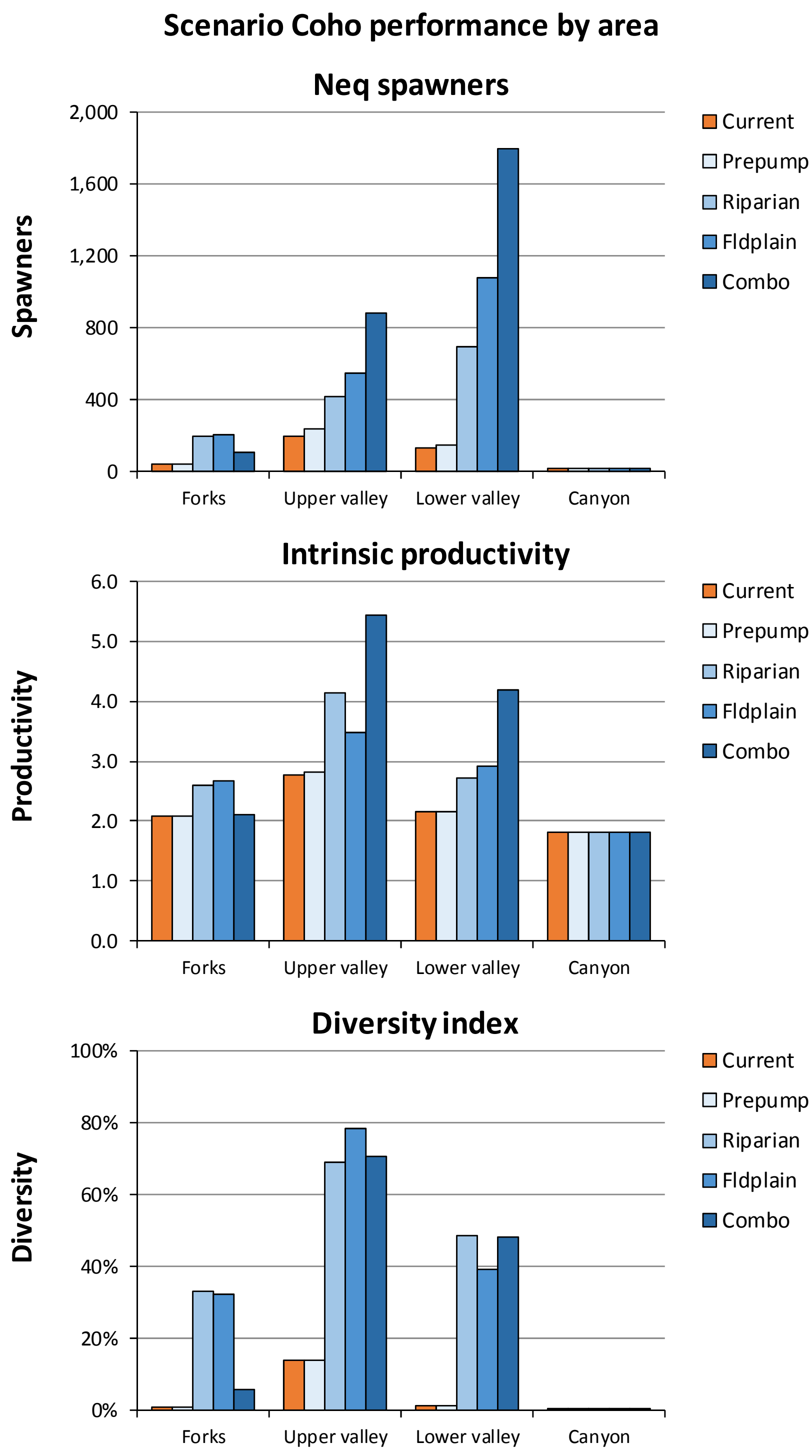

Figure 6-3. Modeling results for the four restoration scenarios compared to the current baseline for the four population components for coho salmon.

Highlights of the Prepumping Flow Restoration scenario are summarized below:

- The geographic scope of restoration covered was limited to the area of major groundwater pumping in the subbasin. Restoration occurred to increase surface flow in affected reaches to what would result from ending groundwater pumping.
- The prepumping wetted channel width at the downstream end of the valley for September was estimated to increase by 50% compared to the current baseline width (Table 6-2), from an average of 40 ft to 60 ft.
- Coho population performance was estimated to produce a modest increase (16%) in Neq spawner abundance (to about 480 spawners) and a very small increase (2.1%) in population productivity at the subbasin scale. The increase in Neq for the upper valley population component was somewhat larger (23.5%).

Highlights of the Riparian Restoration scenario are summarized below:

- The geographic scope of restoration covered was the riparian zone of the entire river system as modeled. Restoration occurred to restore the historical vegetation structure of the entire riparian zone along the mainstem Scott River and all of its tributaries. No changes were assumed to occur for channel structure, either within the riparian zone or within the in-stream channels. No changes to in-stream flow amounts were assumed to occur.
- The Neq abundance of the aggregate coho population was estimated to more than triple its size compared to the current baseline (235% increase)—increasing to about 1,400 spawners. Productivity increased by approximately 24%. The life history diversity metric increased by nearly 1000%.

Highlights of the Floodplain Channels Restoration scenario are summarized below:

- The geographic scope of restoration covered was the areas of the floodplains of the entire river system as modeled. Restoration occurred to restore the historical floodplains channel structure of the entire river system along the mainstem Scott River and all of its tributaries. No changes were assumed to occur to the riparian vegetation, in-stream flow amounts, or channel structure of the main channels of the mainstem Scott River or its tributaries.
- The Neq abundance of the aggregate coho population was estimated to more than quadruple its size compared to the current baseline (356% increase)—increasing to about 1,900 spawners. Productivity increased by approximately 18%. The life history diversity metric increased by about 900%.

Highlights of the Combination Restoration scenario are summarized below:

- The geographic scope of restoration covered was limited to the area of major groundwater pumping in the subbasin. Restoration actions consisted of a combination of actions contained in the other three restoration scenarios—groundwater restoration, riparian restoration, and floodplain channel restoration. The intensity of restoration treatment was reduced by half of the rates applied in the other scenarios. Main stream in-channel structure was also assumed to be partially restored as a result of the riparian and floodplain focused actions.

- The increase in population performance was substantially greater for this scenario than for any of the other scenarios.
    - The Neq abundance of the aggregate coho salmon population was increased by approximately 7x of that in the current baseline (~600%)—increasing to about 2,900 spawners.
    - Productivity was increased by approximately 74%, much more than in any other scenario—increasing to about 4.6 adult returns per spawner.
    - The life history diversity metric increased by about 900%--increasing to about 48%.

These scenario results together indicate that an effective restoration plan would need to address multiple limiting factors and be carried out at a large enough scale to be truly meaningful. The Combination Restoration scenario presented here would likely be capable of producing sufficient resiliency to reduce the risk of extirpation to an appropriate level, although the subpopulation produced in the South and East Forks would remain threatened. The Combination scenario as outlined here does not direct any restoration to habitat within the forks.

6.2.2. Fall Chinook Salmon

Scenario analysis results for fall Chinook salmon are summarized for the aggregate total population and the three major geomorphic areas relevant to this population distinguished in the analysis (Table 6-4; Figure 6-4). Results are compared to the current baseline for Neq abundance, productivity, and life history diversity. Figure 6-5 compares the S-P production curves for the aggregate population for the three restoration scenarios and the current baseline. Figure 6-6 displays population performance metrics among the scenarios for the three geomorphic areas.

Table 6-4. Modeling results for the four restoration scenarios compared to the current baseline for fall Chinook salmon.

Population component	Scenario					Percent change from current			
	Current	Prepump	Riparian	Fldplain	Combo	Prepump	Riparian	Fldplain	Combo
Neq abundance									
All	5,596	6,274	7,052	6,230	7,778	12.1%	26.0%	11.3%	39.0%
Upper valley	360	440	565	519	821	22.2%	56.7%	44.0%	127.7%
Lower valley	2,188	2,504	3,363	2,624	3,907	14.4%	53.7%	19.9%	78.5%
Canyon	2,840	3,096	3,020	2,865	2,961	9.0%	6.3%	0.9%	4.3%
Productivity									
All	4.9	5.0	5.2	4.8	5.0	2.4%	7.3%	-1.7%	2.8%
Upper valley	3.6	3.9	5.1	3.7	5.3	6.9%	41.7%	1.1%	46.5%
Lower valley	3.4	3.5	4.3	3.5	4.2	1.3%	23.8%	1.6%	23.2%
Canyon	5.6	5.8	6.0	5.6	5.7	3.8%	7.3%	0.4%	1.5%
Life history diversity index									
All	68.1%	70.6%	87.9%	71.1%	83.2%	3.6%	29.1%	4.4%	22.1%
Upper valley	80.9%	85.2%	99.6%	88.3%	98.8%	5.3%	23.1%	9.1%	22.1%
Lower valley	50.7%	53.4%	80.6%	54.4%	73.1%	5.2%	59.0%	7.2%	44.0%
Canyon	95.8%	96.6%	97.1%	96.0%	96.3%	0.9%	1.3%	0.2%	0.5%

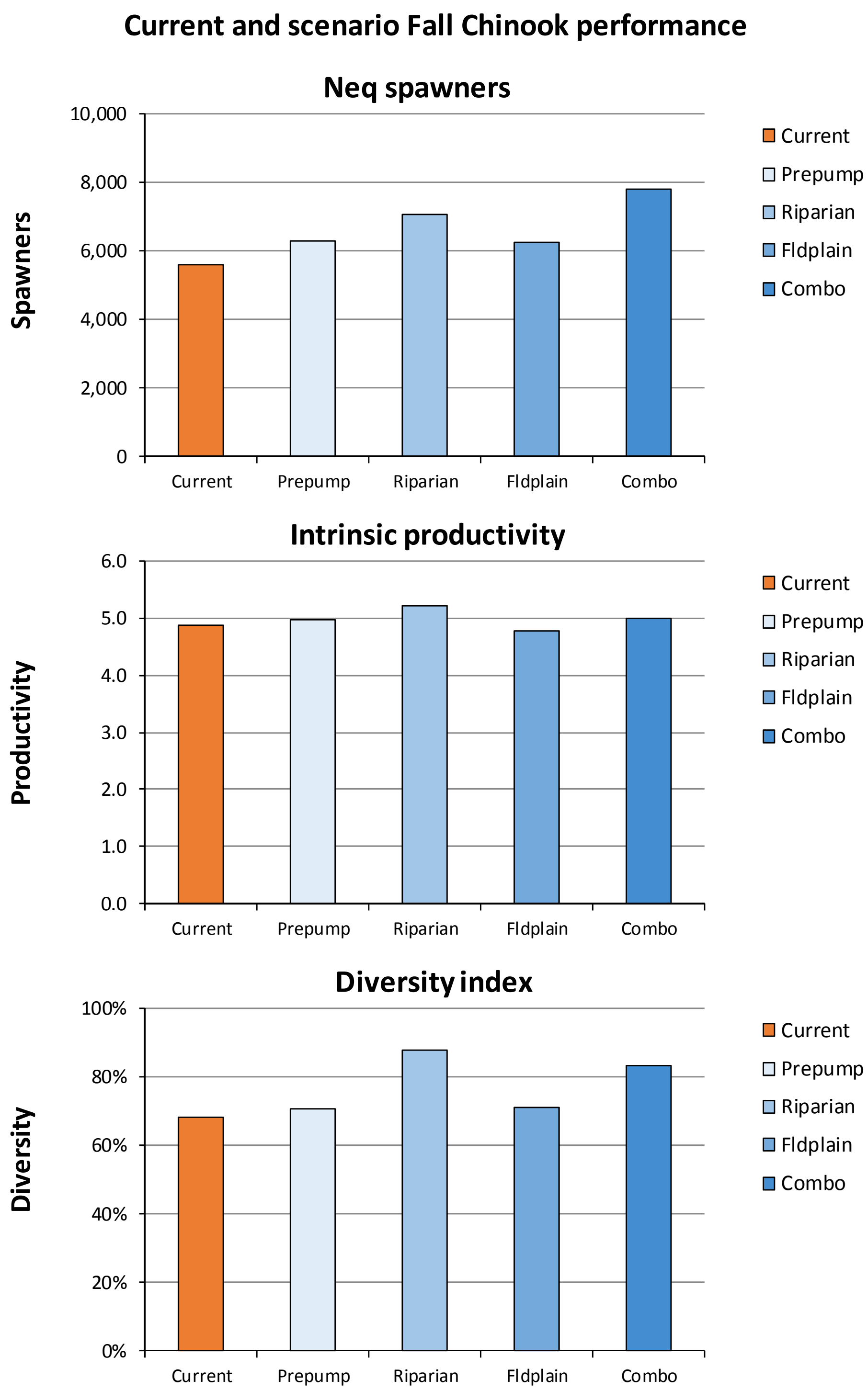

Figure 6-4. Modeling results for the four restoration scenarios compared to the current baseline for fall Chinook salmon.

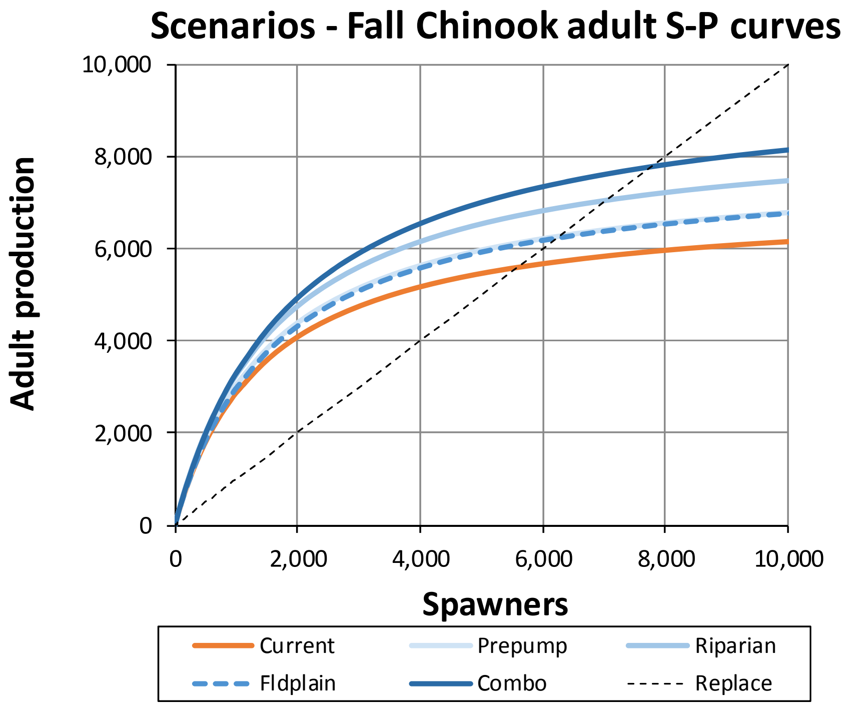

Figure 6-5. Spawner-production curves for the four restoration scenarios compared to the current baseline S-P relationship for fall Chinook salmon measured at the spawner life stage derived from EDT modeling.

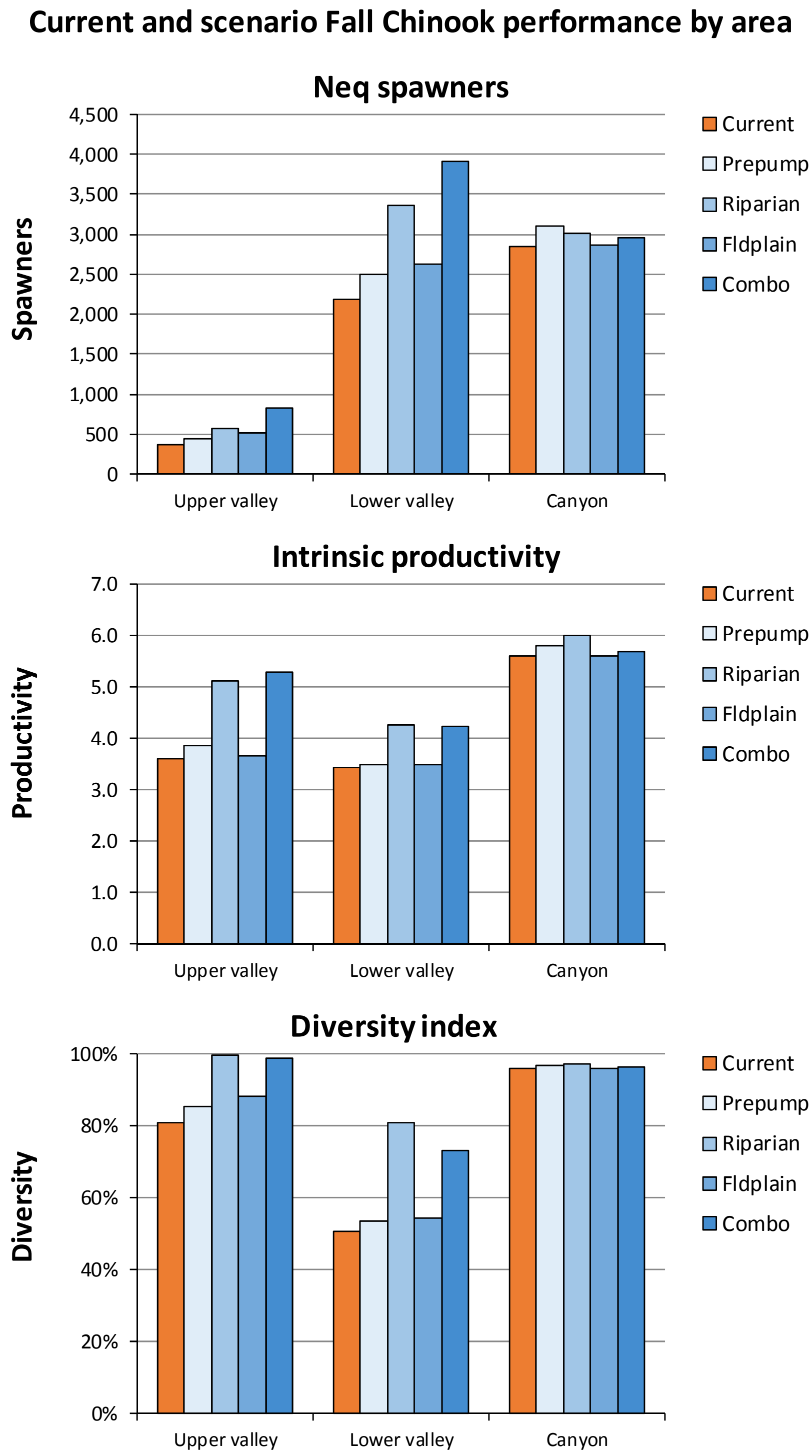

Figure 6-6. Modeling results for the four restoration scenarios compared to the current baseline for the four population components for fall Chinook salmon.

Highlights of the Prepumping Flow Restoration scenario are summarized below:

- The geographic scope of restoration covered was limited to the area of major groundwater pumping in the subbasin. Restoration occurred to increase surface flow in affected reaches to what would result from ending groundwater pumping.
- The prepumping wetted channel width at the downstream end of the valley for September was estimated to increase by 50% compared to the current baseline width (Table 6.1-2), from an average of 40 ft to 60 ft.
- Fall Chinook salmon population performance was estimated to produce a small increase (12%) in Neq spawner abundance (to about 6,300 spawners) and a very small increase (2.4%) in population productivity at the subbasin scale. The increase in Neq for the upper valley population component was somewhat larger (22%).

Highlights of the Riparian Restoration scenario are summarized below:

- The geographic scope of restoration covered was the riparian zone of the entire river system as modeled. Restoration occurred to restore the historical vegetation structure of the entire riparian zone along the mainstem Scott River and all of its tributaries. No changes were assumed to occur for channel structure, either within the riparian zone or within the in-stream channels. No changes to in-stream flow amounts were assumed to occur.
- The Neq abundance of the aggregate fall Chinook salmon population was estimated to increase by about 26% (to about 7,100 spawners) – increasing by about 1,500 spawners. Productivity increased by only 7.3% for the aggregate population but increases were much higher for the upper and lower valley population components. The life history diversity metric increased by about 29%.

Highlights of the Floodplain Channels Restoration scenario are summarized below:

- The geographic scope of restoration covered was the areas of the floodplains of the entire river system as modeled. Restoration occurred to restore the historical floodplains channel structure of the entire river system along the mainstem Scott River and all of its tributaries. No changes were assumed to occur to the riparian vegetation, in-stream flow amounts, or channel structure of the main channels of the mainstem Scott River or its tributaries.
- The Neq abundance of the aggregate fall Chinook salmon population was estimated to increase by about 11% (to about 6,200 spawners) – increasing by about 600 spawners. Productivity was estimated to decrease slightly as a result of an increase in life history diversity (more life history trajectories became sustainable but reduced the overall mean productivity by a slight amount).
- The Floodplains Channels Restoration scenario was most beneficial to coho salmon—the floodplains channels were assumed to be much less used by fall Chinook salmon than by coho salmon.

Highlights of the Combination Restoration scenario are summarized below:

- The geographic scope of restoration covered was limited to the area of major groundwater pumping in the subbasin. Restoration actions consisted of a combination of actions contained in the other three restoration scenarios—groundwater restoration, riparian restoration, and floodplain channel restoration. The intensity of restoration treatment was reduced by half of the rates applied in the other scenarios. Main stream in-channel structure was also assumed to be partially restored as a result of the riparian and floodplain focused actions.
- The increase in Neq abundance was substantially greater for this scenario than for any of the other scenarios. Percentage changes were mixed for productivity and life history diversity were mixed but varied substantially by population component.
    - The Neq abundance of the aggregate fall Chinook salmon population was increased by about 39% over the current baseline—increasing by about 2,200 spawners. Percentage increases were much greater for both of the valley population components.
    - Productivity for the aggregate population was only increased by about 3%, but the percentage increases were much greater for both of the valley population components.
    - The life history diversity metric increased by about 22% for the aggregate population.
    - Overall resiliency of the valley population components was increased substantially in the scenario. The results suggest that the risk of losing these components is reduced substantially with this scenario.

These scenario results together indicate that an effective restoration plan would need to address multiple limiting factors and be carried out at a large enough scale to be truly meaningful. The Combination Restoration scenario presented here would likely be capable of producing sufficient resiliency to reduce the elevated risk of losing the population components produced within the valley. The Combination scenario as outlined here does not direct any restoration to habitat within the canyon geographic area.

6.2.3. Spring Chinook Salmon

Scenario analysis results for spring Chinook salmon are summarized for the aggregate total population and the three major geomorphic areas relevant to this population distinguished in the analysis (Table 6-5, Figure 6-7). Results are compared to the current baseline for Neq abundance, productivity, and life history diversity. Figure 6-8 compares the S-P production curves for the aggregate population for the three restoration scenarios and the current baseline. Figure 6-9 displays population performance metrics among the scenarios for the three geomorphic areas.

Highlights of the Prepumping Flow Restoration scenario are summarized below:

- The geographic scope of restoration covered was limited to the area of major groundwater pumping in the subbasin. Restoration occurred to increase surface flow in affected reaches to what would result from ending groundwater pumping.

- The prepumping wetted channel width at the downstream end of the valley for September was estimated to increase by 50% compared to the current baseline width (Table 6.1-2), from an average of 40 ft to 60 ft.
- Spring Chinook salmon population performance was estimated to produce a small increase (11%) in Neq spawner abundance (to about 6,300 spawners) and a very small increase (3%) in population productivity at the subbasin scale. However, the increase in Neq for the East Fork population component was estimated to be larger (about 24%). The increase in productivity for the East Fork population component was estimated to be small at about 7%.

Highlights of the Riparian Restoration scenario are summarized below:

- The geographic scope of restoration covered was the riparian zone of the entire river system as modeled. Restoration occurred to restore the historical vegetation structure of the entire riparian zone along the mainstem Scott River and all of its tributaries. No changes were assumed to occur for channel structure, either within the riparian zone or within the in-stream channels. No changes to in-stream flow amounts were assumed to occur.
- This restoration scenario produced by far the largest increase VSP metrics of the four scenarios modeled. The Neq abundance of the aggregate spring Chinook salmon population was estimated to increase by about 118% (to about 675 spawners) – increasing by about 360 spawners. However, only modest increases were estimated for productivity. The life history diversity metric increased very substantially under this scenario for all of the population components.

Highlights of the Floodplain Channels Restoration scenario are summarized below:

- The geographic scope of restoration covered was the areas of the floodplains of the entire river system as modeled. Restoration occurred to restore the historical floodplains channel structure of the entire river system along the mainstem Scott River and all of its tributaries. No changes were assumed to occur to the riparian vegetation, in-stream flow amounts, or channel structure of the main channels of the mainstem Scott River or its tributaries.
- The Neq abundance of the aggregate spring Chinook salmon population was estimated to increase by about 50% (to about 470 spawners) – increasing by about 160 spawners. However, productivity was estimated to change little for any of the population components.
- The Floodplains Channels Restoration scenario was most beneficial to coho salmon—the floodplains channels were assumed to be much less used by spring Chinook salmon than by coho salmon.

Highlights of the Combination Restoration scenario are summarized below:

- The geographic scope of restoration covered was limited to the area of major groundwater pumping in the subbasin. Restoration actions consisted of a combination of actions contained in the other three restoration scenarios—groundwater restoration, riparian restoration, and floodplain channel restoration. The intensity of restoration treatment was reduced by half of the rates applied in the other scenarios. Main stream in-channel structure was also assumed to be partially restored as a result of the riparian and floodplain focused actions.

- The spring Chinook salmon Neq for the aggregate population was estimated to be increased by about 41% (to about 440 spawners) with a small increase (8%) in population productivity at the subbasin scale. However, the increase in Neq for the East Fork population component was estimated to be larger (about 24%). The increase in productivity for the East Fork population component was estimated to be small at about 7%.
- This scenario produced mixed percentage changes in the VSP metrics, which were all less than the estimated for the Riparian Restoration scenario:
  - The Neq abundance of the aggregate spring Chinook salmon population was increased by about 41% over the current baseline—increasing by about 130 spawners. Percentage increases were similar for each of the population components.
  - Productivity for the aggregate population was only increased by about 8% and increases were similar for each of the population components.
  - The life history diversity metric increased by between 20 to 63%, depending on the population component.

Although the results of these scenarios might suggest to some readers that spring Chinook salmon performance could be increased sufficiently to produce a sustainable population, the productivities seen in the results suggest otherwise. Productivities of between 2 to 3 adult recruits per spawner estimated in the absence of all fisheries would be reduced by approximately 50% when measured back to the spawning grounds with current fishery exploitation rates.

Spring Chinook salmon in the Scott River subbasin were extirpated in the early 1970s. It is highly unlikely that any of these scenarios implemented in a manner consistent with the assumptions made in the modeling here would be enough to produce meaningful changes in habitat conditions needed for this population.

Table 6-5. Modeling results for the four restoration scenarios compared to the current baseline for spring Chinook salmon.

Population component	Scenario					Percent change from current			
	Current	Prepump	Riparian	Fldplain	Combo	Prepump	Riparian	Fldplain	Combo
Neq abundance									
All	309	345	675	468	437	11.4%	118.0%	51.3%	41.2%
Upper valley	99	99	227	139	130	0.5%	129.7%	40.2%	31.0%
South Fork	54	54	88	78	70	0.6%	62.8%	44.7%	29.7%
East Fork	150	185	350	238	230	23.6%	133.8%	59.2%	53.3%
Productivity									
All	2.3	2.4	2.8	2.3	2.5	3.0%	20.8%	0.1%	8.2%
Upper valley	2.1	2.1	2.9	2.1	2.2	0.0%	36.6%	1.1%	6.0%
South Fork	2.4	2.4	3.2	2.5	2.7	0.0%	33.4%	3.5%	10.2%
East Fork	2.3	2.4	2.5	2.2	2.5	6.6%	11.1%	-3.3%	9.3%
Life history diversity index									
All	19.1%	20.8%	70.1%	28.0%	27.8%	8.7%	266.6%	46.5%	45.3%
Upper valley	22.4%	22.4%	84.1%	34.8%	30.8%	0.0%	274.6%	55.1%	37.3%
South Fork	55.6%	55.6%	94.6%	79.2%	66.7%	0.0%	70.3%	42.6%	20.0%
East Fork	13.1%	16.0%	59.2%	17.5%	21.4%	21.7%	350.6%	33.3%	62.9%

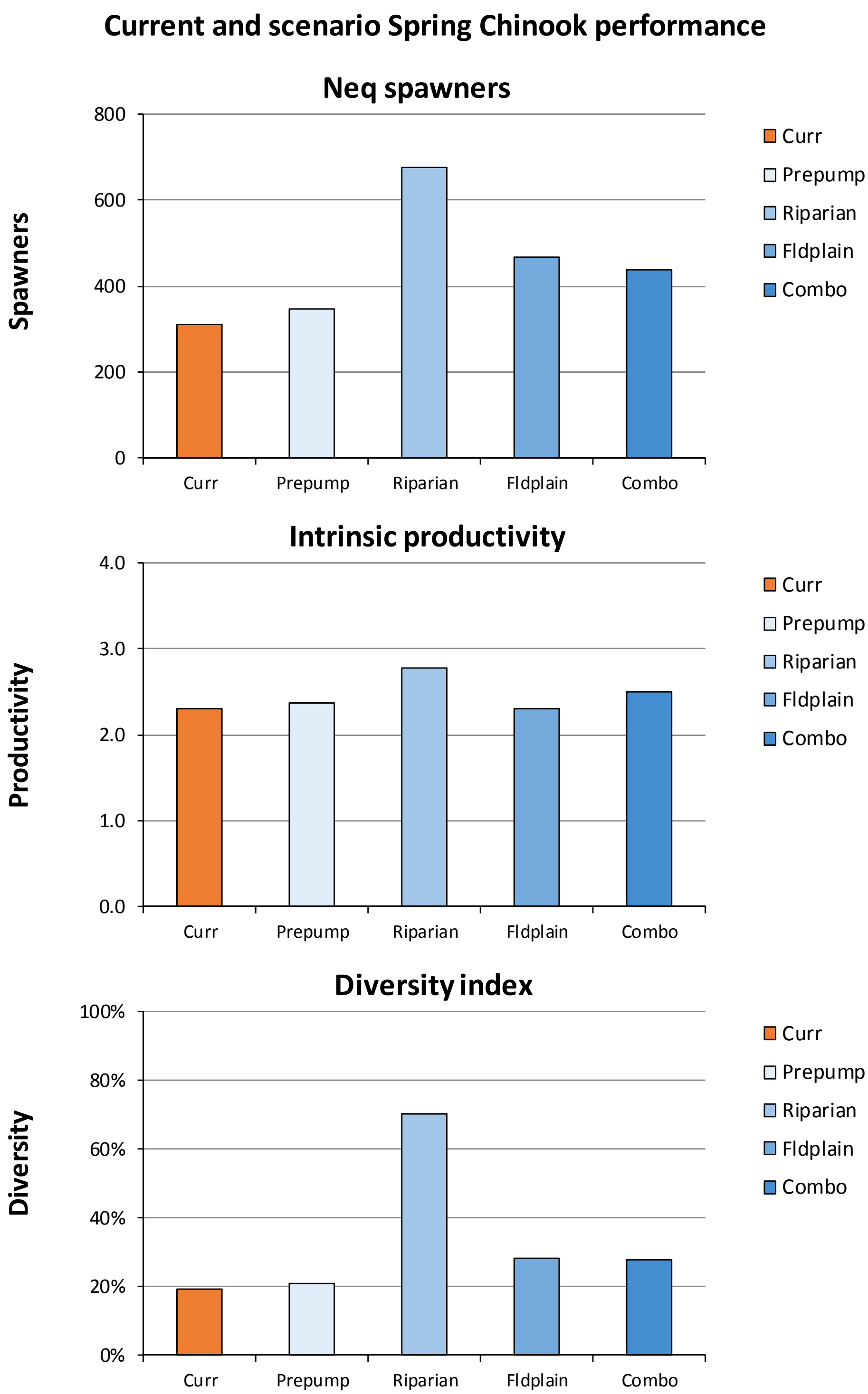

Figure 6-7. Modeling results for the four restoration scenarios compared to the current baseline for spring Chinook salmon.

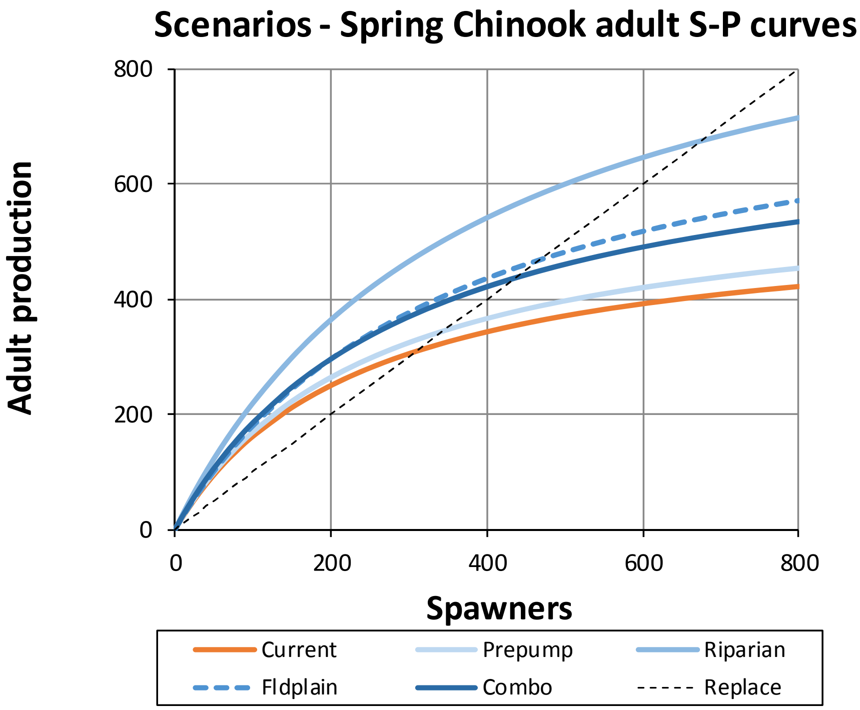

Figure 6-8. Spawner-production curves for the four restoration scenarios compared to the current baseline S-P relationship for spring Chinook salmon measured at the spawner life stage derived from EDT modeling.

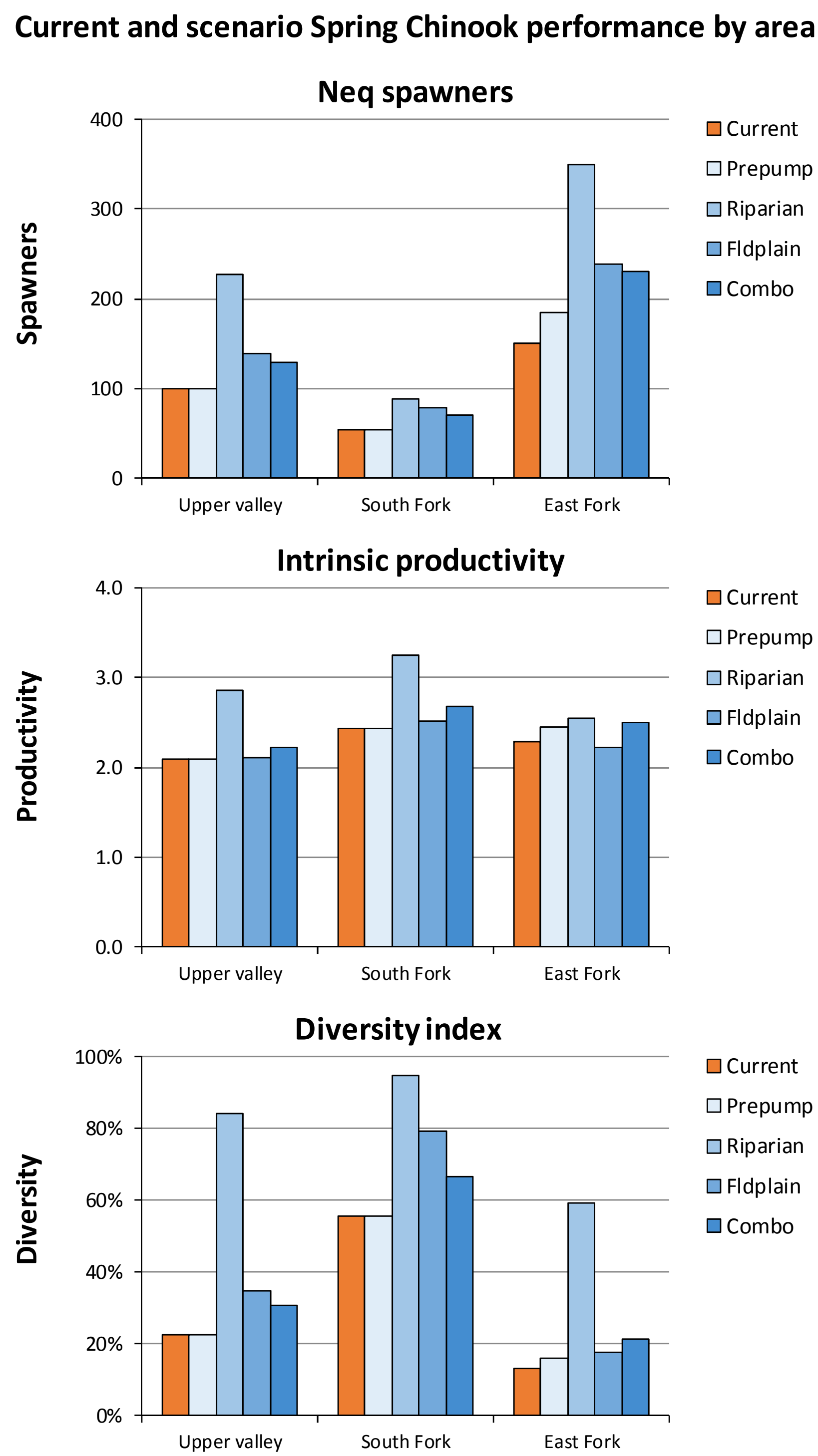

Figure 6-9. Modeling results for the four restoration scenarios compared to the current baseline for the four population components for spring Chinook salmon

7. Conclusions

This assessment was aimed at answering two questions: What is broken in the watershed with respect to salmon performance, and what needs to be fixed? I stated in the Introduction to the report that answering these questions is fundamental to developing an effective restoration and salmon recovery action plan for the subbasin—if indeed such a plan can be developed and implemented.

My conclusions for this assessment are presented in four parts: (1) diagnostic summary, (2) prognosis without intervention, (3) urgent need for intervention, and (4) limitations and uncertainties of analysis.

7.1. Diagnostic Summary

The diagnostic conclusions of this assessment are not surprising. Many of the findings presented herein are consistent with findings and conclusions of other assessments and research (e.g., Moyle et al. 2008; NMFS 2014; CDFW 2015; CDFW 2016). Of the two remaining Scott River salmon populations, the coho population is clearly in trouble—trending downward and subject to wide variation with a spatially fragmented distribution. The other remaining population, fall Chinook, is also arguably in trouble as reflected in its declining percentage of the overall Klamath River natural fall Chinook population. These patterns suggest that both populations have an increasing risk of extirpation, though risk levels differ between the two populations. The modeling results are consistent with and support these observations.

The Scott River subbasin was once a major producer of salmon in the Klamath River basin. These fish populations were a crucial part of a diverse and productive ecosystem, helping to support a rich biota and numerous Native American communities, both within the Scott River subbasin and downstream to the Klamath River mouth.

Today, the abundance, productivity, and life history diversity of the salmon populations are barely a shadow of their former characteristics. Spring Chinook salmon were extirpated in the early 1970s. Coho salmon have declined precipitously, and the risk of extirpation is high and worsening. Fall Chinook salmon have been substantially reduced, increasingly having difficulty of being able to ascend into the valley and its tributaries to spawn; population stability appears precarious and subject to wide variation.

There are multiple reasons for the decline of the Scott River salmon populations. These include a multitude of habitat-related factors within the Scott River subbasin, beginning in the mid-1800s and intensifying since then. Effects of those factors extend throughout the entire Scott River system. These factors encompass practically every aspect of habitat used by salmon in the river system: streamflow, riparian interface, sediment load, habitat type composition, water temperature, channel structure, available food, and others.

As the effect of these factors increased over the past century, harvesting of the salmon runs also increased, both in the ocean and in the Klamath River. Added to these factors were changes that occurred within the mainstem Klamath River due to construction and operations of upriver dams along with other upstream flow management activities managed by the U.S. Bureau of Reclamation. A major hatchery was constructed and operated just downstream of Iron Gate Dam, which has annually released large numbers of fall Chinook and coho salmon. These operations within the mainstem Klamath River are believed to have substantially worsened the effect of fish diseases within the mainstem river, particularly associated with *C. Shasta*.

The combination of all of these factors—their cumulative effect—is ultimately the reason for the decline of the three salmon populations. More recently, climate change-related factors have contributed—exacerbating effects of the other factors. Northern California remains in a long-term drought, which has been particularly severe in recent years.

Within the Scott River subbasin, watershed and biological processes critical to salmon are broken. These include processes that affect hydrologic patterns, sediment transport, water temperature patterns, riparian structure, channel structure and dynamics, connectivity of habitats, cycling of marine-derived nutrients, beaver influences, and others. Among these, the key watershed process that is broken is the flow regime.

The flow regime is the master variable that shapes the riverine ecosystem (Poff et al. 1997) (Figure 7-1). It functioned as the major forcer of many important processes that influenced both physical and biological characteristics of the historical riverine ecosystem. The flow regime consists of five characteristics in flow patterns: magnitude, timing, frequency, duration, and rate of change (Figure 7-2).

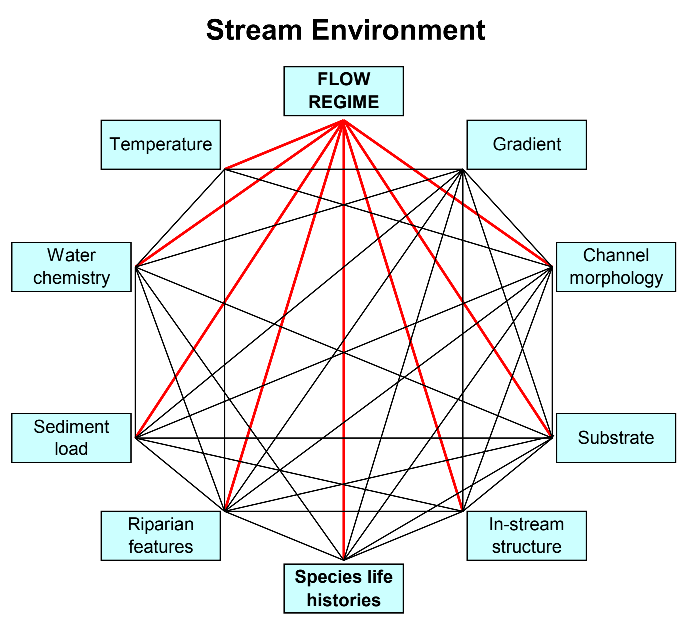

Figure 7-1. Factors affecting habitat and biological processes and functions within the stream environment, showing the important role of the flow regime. Adapted from Giger (1973); taken from SIT and WDFW (2010).

Prior to watershed alterations, these characteristics varied within a range determined by prevailing climate patterns and various watershed features, such as its size, location, topography, configuration, geology, and land cover. Under natural conditions, the patterns and ranges of variation in flow characteristics comprised what is called the watershed's natural flow regime. This regime is the one that salmon populations in the Scott River subbasin adapted to over the millennia prior to the expansive alterations that began in the mid-1800s (Figure 7-2).

The three major causes of the natural flow regime being altered have been (1) land conversion and associated changes in floodplain water storage and channel structure through the Scott Valley and into large parts of the forks, (2) the almost ubiquitous surface water diversions throughout the river system upstream of the canyon, and (3) major groundwater pumping occurring in roughly the lower half of the valley. Periodic droughts resulting from climate cycles and long-term climate change patterns have acted to exacerbate the effects of the human-caused alterations.

These alterations to the flow regime have particularly affected summer and fall low flow levels and connectivity of the river system, both longitudinally along the mainstem river and between the river and its tributaries. Long stretches of the mainstem Scott River are now frequently dry from mid-summer to mid to late fall until the watershed is finally charged by rainfall to reconnect these reaches.

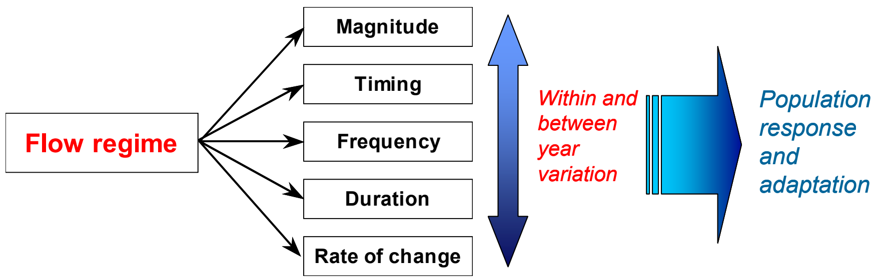

Figure 7-2. Characteristics of the natural flow regime that shape life history adaptations of salmon species in rivers. Based on Poff et al. (1997). Taken from SIT and WDFW (2010).

In addition, the timing of the recharging of the surface water network, together with hyporheic and groundwater flow sources, appears to often be delayed due to water use and extraction through the summer for irrigation. Other contributing factors that have affected the flow regime are changes that occurred to stream channel structure, particularly within the mainstem Scott River, as a result of channel incision, channelization, and disconnection to the floodplain. As noted, current drought conditions have worsened this situation.

As a result of all of these changes to the stream system, salmon population performance characteristics have declined sharply over the period of these watershed alterations. One population has been extirpated, a second population is in imminent threat of extirpation, and the third population is signaling that it too is at risk. These conclusions are supported by the modeling results presented in this report.

In considering the results of the modeling presented herein, it is important to recognize that a more or less average set of conditions as it existed early in this century was modeled. I have not attempted to model the worst case situation with streamflow as it has existed in recent years associated with the current drought. A steady-state average set of conditions has been represented in the model. If I had assumed the steady-state to be the extreme of some of the drought years, modeled results for salmon performance would have been worse.

7.2. Prognosis Without Intervention

The weight of evidence indicates that the prognosis for sustaining the Scott River salmon populations is bleak without major interventions. Salmon habitat conditions within the subbasin are on the whole in extremely poor condition, even though there are some areas of the subbasin in relatively good condition—and a few that could be classified as in very good condition. However, habitats capable of sustaining salmon production are generally disconnected (i.e., not contiguous) from one another, such that the spatial distribution of salmon use in the subbasin is fragmented. These conditions tend to create islands of production scattered in the subbasin—separated both spatially and temporally, which over time greatly increases the risk of extirpation (McElhany et al. 2000).

It bears noting that some relief to the Scott River populations will likely result from dam removal on the mainstem Klamath planned for the next several years upstream of Shasta River. This action is expected to improve the adverse conditions that exist related to C. shasta, though the overall benefit that might occur is uncertain (Bartholomew and Foott 2010). For the sake of Scott River salmon populations, it is important to recognize that the large majority of the environmental factors affecting these populations exists within the Scott River subbasin. Dam removal will not lessen the effects of those factors.

Climate change projections indicate that conditions will continue to worsen for salmon in the subbasin (Beechie et al. 2012; Isaak et al. 2018; Zimmerman 2019). The trajectory for habitat conditions will consequently continue to fragment the populations. Population abundance, productivity, and biological diversity (including spatial structure) can be expected to continue to decline without major, significant steps taken to halt and then reverse the direction of these patterns. Some steps have been taken in recent decades in attempts to reverse these patterns, such as riparian restoration, diversion screening, water leasing, and installation of BDAs. No doubt, these actions have slowed the rate of decline of the populations. But the effectiveness and scale of these measures are insufficient to change the course of the trajectory given the scope and severity of the issues.

Coho salmon have the greatest risk of extirpation given recent patterns of production observed in the subbasin. The modeling results presented in this report support this conclusion. Without some form of major interventions in the subbasin to restore watershed processes and habitats, I expect coho salmon to be extirpated from the subbasin sometime over the next 20 years.

Over this same period, I expect that the percentage of the wild Klamath River fall Chinook aggregate population that will be comprised of Scott River fish to continue to decline—perhaps significantly by 2040, given the pattern seen in Figure 3-8. All of the factors identified in the modeling results will continue to be operative—steadily “winding down” average population performance over time.[17]

---

[17] / The effect of population performance “winding down” so to speak occurs when intrinsic productivity is low for the reasons discussed earlier in this report combined with high environmental variability, which is evident for Scott River populations. This pattern of a steady decline in population performance is usually only evident in relatively long time series data (Lichatowich and Cramer 1979)—data collected over a few years is not sufficient to see the pattern.

I expect the situation for Scott River fall Chinook to also worsen with respect to their access to the Scott Valley for spawning. The frequency of when fall Chinook will not be able to ascend into the valley to spawn is likely to increase over time based on the pattern of fall streamflows suggested in the average September flows in Figure 3-2 (a similar pattern exists for October flows). Climate change patterns will persist. If this occurs, then the reproductive success of Scott River spawners can be expected to decline as a higher proportion of the spawners will spawn in the canyon, causing their eggs to be subjected to higher rates of loss due to bed scour (Hardy and Shaw 2015).[18] This situation will worsen because winter rainfall events are expected to intensify significantly along the Northern California coast in the coming decades as a result of climate change patterns (Warner et al. 2015). Also, high intensity events are expected to occur more frequently. These patterns would adversely affect the reproductive success of fall Chinook spawning in the canyon. Consideration could be given to implementing some form of action within the canyon to reduce the effects of bed scour on incubating eggs, though this would be difficult given the characteristics of the canyon.

Without steps to restore major elements of watershed processes in the subbasin, I expect that fall Chinook salmon will be reduced to extremely few fish by mid to late century.

The root problem is that the resiliency of watershed processes that create and maintain habitats needed to perpetuate the salmon runs has been lost. Similarly, the resiliency of the salmon populations to sustain themselves in the face of environmental variability and climate change has been substantially lost. Intrinsic productivities are low and spatial structure (distribution) has been much reduced and fragmented.

7.3. Urgent Need for Greater Intervention

A comprehensive, aggressive restoration program is urgently needed to reverse the downward trajectories of performance of the two remaining salmon populations in the Scott River subbasin. Without such an effort, the coho population will continue to dwindle, before it finally blinks out. I expect that fall Chinook, while currently more stable than coho, will also continue a downward slide.

The restoration efforts that have occurred over the past several decades have helped both populations – diversion screens, fencing, riparian plantings, water leases – but these efforts, while commendable, can generally be described as insufficient to reverse the declines in performance. A larger, more extensive, and coordinated program is needed.

Such a program would necessitate that both the relevant federal and state entities act to fulfill their public trust responsibilities for these resources. Coho salmon, as both a federal and state ESA-listed species, will assuredly be extirpated in the relatively near future without aggressive intervention to restore resiliency to the population. And arguably, the fall Chinook salmon population should also engender both federal and state intervention actions under public trust responsibilities.

---

[18] / Pacific salmon species are fall and winter spawners. These species generally do not spawn to much extent in canyons due to the much higher probability of redd scour there as a result of winter freshets (Montgomery et al. 1996; Montgomery et al. 1999).

An example of how federal management entities seems to be overlooking issues within the Scott River subbasin is seen in how the Pacific Fisheries Management Council (PFMC) (2019) recently addressed an overfishing status of the Klamath River fall Chinook population. In 2018, PFMC determined that the population was overfished. Consequently, PFMC was required to develop a rebuilding plan for consideration within one year of the overfishing determination. The rebuilding plan is required under the Pacific Coast Salmon Fishery Management Plan (FMP) to consider freshwater survival issues affecting the population, which can include a variety of habitat factors. Part of the plan has been developed and submitted to PFMC. PFMC has directed its Habitat Committee to review the status of essential fish habitat affecting the population. Thus far, the plan appears to have not recognized issues within the Scott River subbasin that need to be addressed.

A restoration program that can truly address the scope and scale of the problem facing both the coho and fall Chinook salmon populations needs to tackle these two overriding within the Scott River subbasin issues:

- The spatial and temporal connectivity of the Scott River system – both longitudinally along the mainstem river and within the many tributaries; and
- Habitat factors that affect intrinsic productivity of the populations.

Both of these issues involve tackling the broken flow regime of the subbasin – in a word: water.

This begs the question: How much water needs to be restored to a free-flowing stream system in the subbasin? I conclude that the volume of surface water exiting the valley needs to be at least the average amount that existed prior to the advent of large scale pumping – this is the amount that was modeled as part of the “prepumping” restoration scenario (see Table 6-2) in this report. Still, this amount of water is a minimum – even that amount is barely sufficient to address the magnitude of the problem. But such an amount could be effective if very substantial and extensive restoration of other habitat factors also occurs, which is the second issue.

The second issue listed above – intrinsic productivity – involves much more than water. The intrinsic productivity of the two populations is determined by habitat quality factors, which includes not just the factors themselves, but their spatial distribution within the subbasin. The principal factors involved—besides water—include an extensive distribution of a diversity of habitat types (both within the main channels and on their floodplains), riparian structure, suitable water temperatures, channel forms and connectivity, wood loads, and sediment load. To address these factors, other watershed processes besides simply flow need to be restored.

To address these two issues raises a most important question: How much restoration is needed? I am not going to attempt to answer that question in this report—it is a thorny question. Frankly, there is not a clear answer to the question at this point in time given many uncertainties.

But the question can be answered qualitatively. Enough restoration is needed to return the aquatic ecosystem to a normative state. A “normative ecosystem” and “normative flow regime” mean that although the subbasin would remain an altered system, it would have a balanced mix of natural and cultural features such that indigenous life histories of salmon populations can be supported.

These terms—“normative ecosystem” and “normative flow regime”—developed for application to salmon recovery planning in the much altered Columbia River system (Williams 2006; Liss et al. 2006), recognize that modern society often causes very substantial changes in watershed processes and functions. Still, in many watersheds, ecological processes can be maintained—or restored—sufficiently to support salmon life histories that were historically adapted to them. Normative refers to the norms of ecological functions and processes characteristic of salmon-bearing streams. These features, when balanced with society’s needs and demands, result in an ecosystem in which both natural and cultural elements can exist in a balance, allowing salmon to thrive and many of society’s present uses of the river to continue, although not without some modification (Liss et al. 2006).

Is it possible to envision a Scott River subbasin restored to normative ecosystem functions, supporting productive, diverse salmon populations—even in the face of climate change, as well as providing for sustainable social, cultural, and economic values within the subbasin?

7.4. Modeling Limitations, Uncertainties, and Variability

Models like EDT provide a quantitative framework for assimilating data, identifying important features of the environment, evaluating the potential effects of watershed and management decisions, and predicting future outcomes (Hilborn and Mangel 1997; Blair et al. 2009; Scheuerell and Hilborn 2009). All such models have inherent limitations due to a variety of uncertainties (Knudsen and Michael 2009). Ultimately, we need to keep in mind that such models are caricatures of complex natural systems (Walters 1986). While extremely useful in helping to simplify such complexity to terms and conditions that provide guidance, it is necessary to remain mindful of their uncertainties.

Models such as EDT have two main types of uncertainty—those related to model structure and those related to model parameters. Model structure uncertainty includes how life stages, movement, transitions between life stages, and spatial structure are modeled—there is uncertainty associated with all of these aspects. EDT is unique among models that assess habitat potential over the salmon life cycle, such as the Shiraz model (Scheuerell and Hilborn 2009), Unit Characteristic Method model (Cramer and Ackerman 2009), and the NOAA Life Cycle model (Beechie et al. 2020), by its use of life history trajectories (Blair et al. 2009). The use of these trajectories enables the model to incorporate life history variation—both temporally and spatially—in ways that those other models do not. While this feature is a strength of EDT, there are limitations in how well the model can capture life history patterns and variation. One recognized limitation is that the trajectories that are employed are pre-defined by the model—they are not what we might call “smart trajectories” that would enable them to be attracted to or repelled by certain environmental conditions. The model deals with this limitation by how trajectory performances across the life cycle are combined (by weighting—see Blair et al. 2009) in the end to estimate population performance. But this is an imperfect solution to a complex natural biological process.

Another model structural limitation of EDT is that it is a steady-state model. This means that it assumes that a set of environmental conditions remain more or less static (even though some amount of year-to-year variation is incorporated into those conditions) over a period of years whereby population performance would come to an equilibrium state. This set of environmental conditions defines a scenario as described in the report. The model estimates population performance metrics for that equilibrium state associated with a scenario. In this sense, the model output is most accurately characterized as representing “habitat potential” for the fish population associated with a specific set of environmental conditions. This is in contrast to a model that would assess the performance of individual separate cohorts, beginning with spawning and ending with spawning of the cohort, which would then produce the next cohort and so on. That type of model could be used to model different environmental conditions associated with each generation, as might occur with year to year differences in temperature, flow, etc.

The other main type of uncertainty associated with the model is related to the estimation of model parameters for each life stage of a species, such as habitat capacity by habitat type (fish/m^2), density-independent survival rates, and the relation between these metrics and environmental conditions. These uncertainties are common to all models like EDT that attempt to model species-specific population performance responses to environmental conditions (Knudsen and Michael 2009). EDT applies a set of benchmark values based on a synthesis of many scientific papers that provide information related to these metrics and relationships. There are many inherent uncertainties associated with this broad range of information. Steel et al. (2009), by performing an extensive sensitivity analysis of the EDT model, suggested that the amount of uncertainty in these benchmark values, which are internal parameters to the model, may be greater than the uncertainty in stream attribute inputs applied in a typical EDT application. The EDT model is not structured to produce confidence limits on the model outputs. Despite these uncertainties, Steel et al. (2009) concluded that the model’s identification of high priority reaches for restoration and protection is relatively robust.

Other specific uncertainties associated with the Scott River application of the EDT model bear particular mention here:

- The historical characterizations of the subbasin, associated salmon performance, spawning distributions, and age structure (Chinook salmon) are uncertain in many aspects;
- There are differing levels of uncertainty associated with the various environmental attributes—for both baseline sets of conditions as well as predicted outcomes under the restoration scenarios;
- Considerable uncertainty exists with flow levels throughout the river system network because of the limited quantitative data available across the system—still, the procedure applied produced results consistent with those available data and reflect reasonable seasonal patterns;
- Substantial uncertainty exists about the potential adverse effects of on-going fragmentation of both the fall Chinook and coho salmon populations on future performance and population viability—such potential effects were not incorporated into the model though adverse effects are expected;
- Substantial uncertainty exists about the effectiveness of potential restoration actions in the subbasin to restore flow connectivity, habitat types, and productive floodplain channels given the magnitude of watershed alterations that have occurred over time; and

- Uncertainties exists about the effects of continued climate change on Scott River watershed processes and on salmon performance within the watershed, as well the effects of climate change on marine survival of Scott River salmon.

A final comment on my part regarding all of these uncertainties is worth noting. I have applied the EDT model to many watersheds and salmon populations in the Pacific Northwest—from small watersheds and populations (e.g., summer chum salmon in small streams that enter Hood Canal within Puget Sound) to large ones (e.g., Chinook salmon in major subbasins of the Columbia River system). I have also reviewed other similar applications done by other biological teams in numerous other watersheds in the Pacific Northwest. I have been involved in many other types of environmental assessments related to salmon performance over many decades in my career. All of these assessments contained uncertainties—to various degrees. This begs the question: How does the Scott River application compare to these other assessments? I consider this assessment of Scott River salmon performance to be scientifically sound and well supported. The conclusions and guidance provided through this assessment are credible and defensible.

8. References

Ackerman, N., T. Nickelson, B. Fox, R. Sutton, and S. Cramer. 2007. Estimating the capacity of the Klamath Basin to rear coho. Technical Memorandum 5 of 8. Klamath Coho Integrated Modeling Framework Technical Memorandum Series. Submitted to the Bureau of Reclamation Klamath Basin Area Office on April 30, 2007.

Agrawal, A., R. Schick, E. Bjorkstedt, R.G. Szerlong, M. Goslin, B. Spence, T. Williams, and K. Burnett. 2005. Predicting the potential for historical coho, Chinook and steelhead habitat in northern California. U. S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-379.

Alexander, J. D., J. L. Bartholomew, K. A. Wright, N. A. Som, and N. J. Hetrick. 2016. Integrating models to predict distribution of the invertebrate host of myxosporean parasites. Freshwater Science. Online Early. doi: 10.1086/688342.

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

Barnhart, R.A. 1994. Salmon and steelhead populations of the Klamath-Trinity Basin, California. Pages 73-97 *in* T.J. Hassler (ed.) Klamath Basin Fisheries Symposium. Humboldt State University, Arcata, CA.

Bartholomew, J.L., and J.S. Foott. 2010. Compilation of information relating to myxozoan disease effects to inform the Klamath Basin Restoration Agreement. Secretarial Determination Overview Report.

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

Beechie, T., H. Imaki, J. Greene, A. Wade, H. Wu, G. Pess, P. Roni, J. Kimball, J. Stanford, P. Kiffney, and N. Mantua. 2013. Restoring salmon habitat for a changing climate. River Research and Applications 29:939–960.

Beechie, T.J., C. Nicol, C.F., J. Jorgensen, J. Thompson, G. Seixas, J. Chamberlin, J. Hall, B.T. Padgham, P. Kiffney, S. Kubo, and J. Keaton. 2020. Modeling effects of habitat change and restoration alternatives on salmon in the Chehalis River Basin using a salmonid life-cycle model. Phase I Project Report prepared for Washington Department of Fish and Wildlife, Olympia, WA.

Beverton, R.J.H., and S.J. Holt. 1957. On the Dynamics of Exploited Fish Populations. Chapman and Hall, London, UK.

Blair, G.R., L.C. Lestelle, and L.E. Mobrand. 2009. The Ecosystem Diagnosis and Treatment model: a tool for evaluating habitat potential for salmonids. Pages 289-309 *in* E.E. Knudsen and J.H. Michael Jr. (eds.) Pacific Salmon Environment and Life History Models: Advancing Science for Sustainable Salmon in the Future. American Fisheries Society. Bethesda, MD.

Boydstun, L.B., and T. McDonald. 2005. Action plan for monitoring California's coastal salmonids. WASC-3-1295. Final report to NOAA Fisheries, Santa Cruz, CA.

Bradford, M.J., G.C. Taylor, and J.A. Allan. 1997. Empirical review of coho salmon smolt abundance and the prediction of smolt production at the regional level. Transactions of the American Fisheries Society 126:49-64.

Burnett, K., G. Reeves, D. Miller, S. Clarke, K. Christiansen, and K. Vance-Borland. 2003. A first step toward broad-scale identification of freshwater protected areas for Pacific salmon and trout in Oregon, USA. Pages 144-154 *in* J. P. Beumer, A. Grant, and D. C. Smith (eds.) Aquatic protected areas: what works best and how do we know? Proceedings of the World Congress on Aquatic Protected Areas, Cairns, Australia, August 2002.

Carmichael, R.W., and B.J. Taylor. 2009. Conservation and recovery plan for Oregon steelhead populations in the Middle Columbia River Steelhead Distinct Population Segment. Oregon Department of Fish and Wildlife, La Grande, OR.

CDFG (California Department of Fish and Game). 1990. Status and management of spring-run Chinook salmon. Report by Inland Fisheries Division, CDFG. May 1990.

CDFG (California Department of Fish and Game). 1998. A status review of the spring-run Chinook salmon (*Oncorhynchus tshawytscha*) in the Sacramento River drainage. Report to the Fish and Game Commission, Candidate Species Status Report 98-01, Sacramento, CA.

CDFG (California Department of Fish and Game). 2002. Status review Of California coho salmon north Of San Francisco. Report to the California Fish and Game Commission.

CDFG (California Department of Fish and Game). 2002a. Stream inventory report – Cabin Creek Meadows. Unpublished report.

CDFG (California Department of Fish and Game). 2002b. Stream inventory report – East Fork Scott River. Unpublished report.

CDFG (California Department of Fish and Game). 2002c. Stream inventory report – Grouse Creek. Unpublished report.

CDFG (California Department of Fish and Game). 2002d. Stream inventory report – Houston Creek. Unpublished report.

CDFG (California Department of Fish and Game). 2002e. Stream inventory report – Kangaroo Creek. Unpublished report.

CDFG (California Department of Fish and Game). 2002f. Stream inventory report – Rail Creek. Unpublished report.

CDFG (California Department of Fish and Game). 2004. Stream inventory report – Sugar Creek. Unpublished report.

CDFG (California Department of Fish and Game). 2005. Recovery strategy for California coho salmon. Report to the California Fish and Game Commission. Sacramento, CA.

CDFG (California Department of Fish and Game). 2008a. Stream inventory report – East Fork Scott River. Unpublished report.

CDFG (California Department of Fish and Game). 2008b. Stream inventory report – Rail Creek. Unpublished report.

CDFW (California Department of Fish and Wildlife). 2016. Scott River brood year 2013 juvenile coho salmon PIT tagging study. Report dated August 5, 2016. California Department of Fish and Wildlife, Yreka, CA.

CDFW (California Department of Fish and Wildlife). 2017. Interim instream flow criteria for the protection of fishery resources in the Scott River watershed, Siskiyou County. Report dated February 6, 2017. California Department of Fish and Wildlife, Yreka, CA.

CDFW (California Department of Fish and Wildlife), NOAA-Fisheries, Scott River Water Trust, Siskiyou Resource Conservation District, U.S. Forest Service. 2015. Cooperative report of the Scott River coho salmon rescue and relocation effort, 2014 drought emergency. Joint report of multi-agency effort. California Department of Fish and Wildlife, Yreka, CA.

CDWR (California Department of Water Resources). 1965. Land and Water Use in Shasta-Scott Valleys Hydrographic Unit, Volume I: Text, Bulletin No. 94–95.

CDWR (California Department of Water Resources). 2004. California's Groundwater, Scott River Valley Groundwater Basin. Bulletin 118.

Chapman, D.W. 1966. Food and space as regulators of salmonid populations in streams. American Naturalist 100:345-357.

Clayton T.L. 2006. 2005 Fall Chinook salmon spawning ground survey. USDA Forest Service Klamath National Forest. Fort Jones, CA.

CHRP (California Hatchery Review Project). 2012. Trinity River hatchery spring Chinook program report. Appendix VIII. Appendix to final report of California Hatchery Scientific Review Group. 2012. California Hatchery Review Statewide Report. Prepared for the US Fish and Wildlife Service and Pacific States Marine Fisheries Commission. April 2012.

Cramer, S.P., and N.K. Ackerman. 2009. Prediction of stream carrying capacity for steelhead: the unit characteristic method. Pages 255-288 *in* E.E. Knudsen and J.H. Michael Jr. (eds.) Pacific Salmon Environment and Life History Models: Advancing Science for Sustainable Salmon in the Future. American Fisheries Society. Bethesda, MD.

Cramer Fish Sciences. 2010. Scott River spawning gravel evaluation and enhancement plan. Final report, submitted to Pacific States Marine Fisheries Commission & California Department of Fish and Game.

Davis, J. 1997. Scott River watershed CRMP Committee. Final report, October 1995 – December 1996. Siskiyou Resource Conservation District. Prepared for U.S. Fish and Wildlife Service, Klamath Fisheries Restoration Program.

Deas, M.L., and S. Tanaka. 2004. Scott River water balance study – data analysis and model review. Watercourse Engineering. Napa, CA.

Deas, M.L., and S.K. Tanaka. 2006. Scott River water supply indices: Year types for the Scott River Basin, prepared for the Siskiyou RCD. Watercourse Engineering. Napa, CA.

Debrick, A., and S. Stenhouse. 2014. Shasta and Scott River juvenile salmonid outmigrant study. Final report, P0710307. California Department of Fish and Wildlife, Yreka, CA.

Doyle, E., J. Arterburn, and R. Klett. *In press*. Integrating ecosystem models with long-term monitoring to support salmon recovery. Submitted to Fisheries.

Drake, D., K. Tate, and H. Carlson. 2000. Analysis shows climate-caused decreases in Scott River fall flows. California Agriculture 54(6):46–49.

ESA. 2009. Scott River Watershed-wide Permitting Program. Final Environmental Impact Report (FEIR) Volume 1: Revisions to the Draft EIR Text (Vol. 1). Prepared for California Department of Fish and Game.

Foglia L, McNally A, Harter T. 2013. Coupling a spatiotemporally distributed soil water budget with stream-depletion functions to inform stakeholder-driven management of groundwater-dependent ecosystems. Water Resources Research 49:7292–310.

Foott J.S., R. J.L. Barthomew, R.W. Perry, and C.E. Walker. 2011. Conceptual model for disease effects in the Klamath River. Whitepaper prepared for the Klamath Basin Restoration Agreement Secretarial Overview Report Process.

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.

Fraser, F.J. 1969. Population density effects on survival and growth of juvenile coho salmon and steelhead trout in experimental stream-channels. Pages 253-266 *in* Northcote, T.G. (ed.) Symposium on Salmon and Trout in Streams. Institute of Fisheries, University of British Columbia. Vancouver, BC.

Fujiwara, M., M.S. Mohr, A. Greenberg, J.S. Foott, and J.L. Bartholomew. 2011. Effects of *ceratomyxosis* on population dynamics of Klamath fall-run Chinook salmon. Transactions of the American Fisheries Society 140:1380–1391.

Giger, R.D. 1973. Streamflow requirements of salmonids. Oregon Wildlife Commission, Anadromous Fish Project, Final Report. AFS-62-1. Portland, OR.

Gilbert, C.H. 1912. Age at maturity of Pacific coast salmon of the genus *Oncorhynchus*. Bulletin of the U.S. Fisheries Commission. 32:57-70.

Gilbertson, L., T. Jurasin, R. Coshow, and M. Miller. 2021. Run-type composition of juvenile Chinook salmon in the upper Chehalis River Basin in 2020. Technical Report Series 2021-1, Quinault Indian Nation Department of Fisheries. Taholah, WA.

Hankin, D. G. 1990. Effects of month of release of hatchery- reared Chinook salmon on size at age, maturation schedule and fishery contribution. Oregon Department of Fish and Wildlife, Information Report 90-4.

Hardy, T.B., and T.A. Shaw. 2015. An evaluation of the anadromous fish interim instream flow need for the lower Scott River in Siskiyou County, California. Phase I Final Report. Report prepared for the Yurok Tribe. Watershed Systems Group, Inc. San Marcos, TX.

Hare, S.R., and N.J. Mantua. 2001. An historical narrative on the Pacific Decadal Oscillation, interdecadal climate variability and ecosystem impacts. Report of a talk presented at the 20th NE Pacific Pink and Chum Workshop, Seattle, WA, March 22, 2001.

Hathaway, D.L. 2012. Stream depletion impacts associated with pumping from within or beyond the "interconnected groundwater" area as defined in the 1980 Scott Valley Adjudication. Memorandum to C. Tucker, August 27, 2012. S.S. Papadopulos & Associates.

Healey, M.C. 1991. Life history of chinook salmon (*Oncorhynchus tshawytscha*). Pages 311-349 *in* C. Groot and L. Margolis (eds.) Pacific Salmon Life Histories. University of British Columbia Press, Vancouver, BC.

Healey, M.C., and W.R. Heard. 1984. Inter- and intra-population variation in the fecundity of chinook salmon (*Oncorhynchus tshawytscha*) and its relevance to life history theory. Canadian Journal of Fisheries and Aquatic Sciences. 41: 476-483.

Hilborn, R., and M. Mangel. 1997. The Ecological Detective: Confronting Models with Data. Princeton University Press, Princeton, NJ.

Hilborn, R., and C. J. Walters. 1992. Quantitative Fish Stock Assessment. Chapman and Hall, London, UK.

Hillemeier, D., T. Soto, S. Silloway, A. Corum, M. Kleeman, and L. Lestelle. 2009. The role of the Klamath River mainstem corridor in the life history and performance of juvenile coho salmon (*Oncorhynchus kisutch*) - May 2007 – May 2008. Report submitted to the U.S. Bureau of Reclamation, Klamath Area Office, Klamath Falls, OR.

Holmberg, J.J. 1972. Salmon in California. U.S. Bureau of Reclamation. Sacramento, CA.

Holt, C. 1999. Spawning ground survey field manual. Unpublished report, Quinault Department of Natural Resources, Taholah, WA.

ICTRT (Interior Columbia Basin Technical Recovery Team). 2007. Viability criteria for application to Interior Columbia basin salmonid ESUs. ICTRT Review Draft Report to NOAA Fisheries. Portland, OR.

Isaak, D., S. Wenger, E. Peterson, J. Ver Hoef, D. Nagel, C. Luce, S. Hostetler, J. Dunham, B. Roper, S. Wollrab, G. Chandler, D. Horan, S. Parkes-Payne. 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(3): 566-587.

Kaje, 2008. Instream flow Viable Salmonid Populations (VSP) workshop summary. Shorelands and Environmental Assistance (SEA) Program, Washington State Department of Ecology. Olympia, WA.

Knechtle, M. 2009. Scott River salmon studies 2008. Final report, California Department of Fish and Wildlife, Northern Region Klamath River Project. Yreka, CA.

Knechtle, M., and D. Chesney. 2017. 2016 Scott River salmon studies. Final report, California Department of Fish and Wildlife, Northern Region Klamath River Project. Yreka, CA.

Knechtle, M., and D. Guidice. 2018. 2017 Scott River salmon studies. Final report, California Department of Fish and Wildlife, Northern Region Klamath River Project. Yreka, CA.

Knechtle, M., and D. Guidice. 2019. 2018 Scott River salmon studies. Final report, California Department of Fish and Wildlife, Northern Region Klamath River Project. Yreka, CA.

Knudsen, E.E, and J.H. Michael. 2009. Introduction: the past, present, and future of Pacific salmon environmental and life history models. Pages 3-19 *in* E.E. Knudsen and J.H. Michael Jr. (eds.) Pacific Salmon Environment and Life History Models: Advancing Science for Sustainable Salmon in the Future. American Fisheries Society. Bethesda, MD.

KRTT (Klamath River Technical Team). 2019. Ocean abundance projections and prospective harvest levels for Klamath River fall Chinook, 2019 season. Report prepared for the Pacific Fisheries Management Council.

Lawson, P.W., E.P. Bjorkstedt, M.W. Chilcote, C.W. Huntington, J.S. Mills, K.M.S. Moore, T.E. Nickelson, G.H. Reeves, H.A. Stout, T.C. Wainwright, and L.A. Weitkamp. 2007. Identification of historical populations of coho salmon (*Oncorhynchus kisutch*) in the Oregon Coast Evolutionarily Significant Unit. U. S. Department of Commerce, NOAA Technical Memorandum NOAA-NMFS-NWFSC-79.

Lestelle, L.C. 2005. Guidelines for rating Level 2 Environmental Attrributes in Ecosystem Diagnosis and Treatment. Report prepared for Northwest Power Planning Council. Mobrand Biometrics, Inc. Vashon, WA.

Lestelle, L.C. 2007. Coho salmon (*Oncorhynchus kisutch*) life history patterns in the Pacific Northwest and California. Final report submitted to the U.S. Bureau of Reclamation, Klamath Area Office, Klamath Falls, OR.

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

Lestelle, L. 2012. Effects of Dwinnell Dam on Shasta River salmon and considerations for prioritizing recovery actions. Report prepared for the Karuk Tribe, Happy Camp, CA.

Lestelle, L. 2013. Historic run sizes of Scott River salmon. Technical memorandum to Dave Hillemeier, Yurok Tribal Fisheries Program. Dated January 7, 2013. Biostream Environmental, Poulsbo, WA.

Lestelle, L.C., G.R. Blair, L.E. Mobrand. 2005a. Assessment of summer chum performance in Hood Canal and the eastern Strait of Juan de Fuca. Report prepared for Hood Canal Coordinating Council. Mobrand Biometrics, Inc. Vashon, WA.

Lestelle, L. C., G.S. Morishima, and T.D. Cooney. 1984. Determining spawning escapement goals for wild coho salmon on the Washington north coast. Pages 243-254 in J.M. Walton and D.B. Houston (eds.). Olympic Wild Fish Conference. Peninsula College, Port Angeles, WA.

Lestelle, L.C., L.E. Mobrand, J.A. Lichatowich, and T.S. Vogel. 1996. Applied ecosystem analysis - a primer, EDT: the Ecosystem Diagnosis and Treatment Method. Project No. 9404600, Bonneville Power Administration, Portland, OR.

Lestelle, L.C., L.E. Mobrand, and W.E. McConnaha. 2004. Information structure of Ecosystem Diagnosis and Treatment (EDT) and habitat rating rules for Chinook salmon, coho salmon, and steelhead trout. Report prepared for Northwest Power Planning Council. Mobrand Biometrics, Inc. Vashon, WA.

Lestelle, L., R. Brocksmith, T. Johnson, and N. Sands. 2014. Guidance for updating recovery goals for Hood Canal summer chum populations and subpopulation-specific recovery targets. Report submitted to the Hood Canal Coordinating Council and NOAA Fisheries. Poulsbo, WA.

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

Lestelle, L., N. Sands, T. Johnson, and M. Downen. 2018. Recovery goal review and updated guidance for the Hood Canal Summer Chum Salmon ESU. Report submitted to the Hood Canal Coordinating Council and NOAA Fisheries. Poulsbo, WA.

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

Lichatowich, J.A. and S. Cramer. 1979. Parameter selection and sample sizes in studies of anadromous salmonids. Oregon Department of Fish and Wildlife, Information Report Series No. 80-l.

Lichatowich, J., L.E. Mobrand, L. Lestelle, and T. Vogel. 1995. An approach to the diagnosis and treatment of depleted Pacific salmon populations in freshwater ecosystems. Fisheries 20(1): 10-18.

Liss, W.J., J.A. Stanford, J.A. Lichatowich, R.N. Williams, C.C. Coutant, P.R. Mundy, and R.R. Whitney. 2006. A foundation for restoration. Pages 51-98 *in* R.N. Williams (ed.) Return to the River: Restoring Salmon to the Columbia River. Elsevier Academic Press, Burlington.

Mack, S., Geology and Ground-Water Features of Scott Valley, Siskiyou County California. U.S. Geological Survey Water-Supply Paper 1462.

Magranet, L. 2016. 2015 monitoring report. Siskiyou Resource Conservation District report prepared for the Scott River Water Trust.

Massie, M., and K. Patterson. 2019. 2019 Scott River juvenile salmonid outmigrant study. Final report, Fisheries Restoration Grants Program, P1610529. California Department of Fish and Wildlife, Yreka, CA.

Massie, M., and M. Anderson. 2019. Scott River juvenile salmonid outmigrant study. Final report, Fisheries Restoration Grants Program, P1610529. California Department of Fish and Wildlife, Yreka, CA.

McConnaha, W., J. Walker, K. Dickman, M. Yelin. 2017. Analysis of salmonid habitat potential to support the Chehalis Basin Programmatic Environmental Impact Statement. Prepared by ICF Portland, OR for Anchor QEA, Seattle, WA.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-NWFSC42.

Miller, R.J., and E.L. Brannon. 1982. The origin and development of life history patterns in Pacific salmonids. Pages 296-309 *in* E.L. Brannon and E. 0. Salo (eds.), Proceedings of the Salmon and Trout Migratory Behavior Symposium. University of Washington Press, Seattle, WA.

Mobrand Biometrics, Inc. 2003a. Assessment of salmon and steelhead performance in the Chehalis River basin in relation to habitat conditions and strategic priorities for conservation and recovery actions. Final report prepared for Chehalis Basin Fisheries Task Force and Washington Department of Fish and Wildlife. Mobrand Biometrics, Inc. Vashon, WA.

Mobrand Biometrics, Inc. 2003b. Strategic priorities for salmon conservation and recovery actions in WRIAs 10 and 12 -- development of salmonid recovery plans for the White, Puyallup, Chambers-Clover, and Hylebos watersheds. Final report prepared for Pierce County. Mobrand Biometrics, Inc. Vashon, WA.

Mobrand, L.E., and L.C. Lestelle. 1997. Application of the Ecosystem Diagnosis and Treatment Method to the Grande Ronde Model Watershed Project. Contract number 94AM33243, Final Report. Bonneville Power Administration, Portland, OR.

Mobrand, L.E., J.A. Lichatowich, L.C. Lestelle, and T.S. Vogel. 1997. An approach to describing ecosystem performance "through the eyes of salmon". Canadian Journal of Fisheries and Aquatic Sciences 54: 2964-2973.

Moffett, J.W., and S.H. Smith. 1950. Biological investigations of the fishery resources of Trinity River, California. U.S. Fish and Wildlife Service Special Scientific Report, Fisheries No. 12, U.S. Fish and Wildlife Service, Washington, DC.

Montgomery, D.R., E.M. Beamer, G.R. Pess, and T.P. Quinn. 1999. Channel type and salmonid distribution and abundance. Canadian Journal of Fisheries and Aquatic Sciences 56: 377-387.

Montgomery, D.R., J.M. Buffington, N.P. Peterson D. Scheutt-Hames, and T.P. Quinn. 1996. Streambed scour, egg burial depths and the influence of salmonid spawning on bed surface mobility and embryo survival. Canadian Journal of Fisheries and Aquatic Sciences 53: 1061-1070.

Morris, W.F., and D.F. Doak. 2002. Quantitative Conservation Biology: Theory and Practice of Population Viability Analysis. Sinauer Associates, Inc, Sunderland, MA.

Mount, J.F., P.B. Moyle, and S.M. Yarnell. 2003. Ecology & geomorphology of streams: a study of juvenile salmonid habitat in select Scott River tributaries. Report sponsored by the University of California Presidential Chair in Undergraduate Education and the Roy Shlemon Chair in Applied Geosciences.

Moussalli, E., and R. Hilborn. 1986. Optimal stock size and harvest rate in multistage life history models. Canadian Journal of Fisheries and Aquatic Sciences 43:135-141.

Moyle, P.B. 2002. Inland Fishes of California. University of California Press, Berkeley, CA.

Moyle, P.B., J.A. Israel, and S.A. Purdy. 2008. Salmon, steelhead, and trout in California: Status of an emblematic fauna. Report commissioned by California Trout. Center for Watershed Sciences, University of California, Davis.

Naiman, R.J., C.A. Johnston, and J.C. Kelley. 1988. Alteration of North American streams by beaver. BioScience 38: 753–762.

Naman, S. 2005. Water utilization and fisheries issues in the Scott River Basin, California, Humboldt State University, November 18, 2005.

NCRWB (North Coast Regional Water Board). 2011. Scott River Watershed Water Quality Compliance and Trend Monitoring Plan. Prepared by the North Coast Regional Water Board staff. 07/12/2011 version.

Nicholas, J.W., and D.G. Hankin. 1988. Chinook salmon populations in Oregon coastal basins: description of life histories and assessment of recent trends in run strengths. Oregon Department of Fish and Wildlife Information Report 88-1, Portland, OR.

NCRWQCB (North Coast Regional Water Quality Control Board). 2005. Staff Report for the Action Plan for the Scott River Watershed Sediment and Temperature Total Maximum Daily Loads.

NMFS (National Marine Fisheries Service). 2014. Final Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (Oncorhynchus kisutch). National Marine Fisheries Service, Arcata, CA.

NMFS (National Marine Fisheries Service). 2020. Fisheries Off West Coast States; West Coast Salmon Fisheries; Rebuilding Chinook Salmon Stocks. Federal Register [Docket No. 201119–0308, 27 November 2020] 85(229):75920–75923.

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

PFMC (Pacific Fishery Management Council). 2019. Salmon rebuilding plan for Klamath River fall Chinook. Pacific Fishery Management Council. Portland, OR.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. Bioscience 47:769-784.

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

Pollock, M., T. Beechie, J.M. Wheaton, C. Jordan, N. Bouwes, N. Weber, and C. Volk. 2014. Using beaver dams to restore incised stream ecosystems. BioScience 64:279-290.

Prince, D.J., S.M. O'Rourke, T.Q. Thompson, O.A. Ali, H.S. Lyman, I.K. Saglam, … 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.

Quigley, D. 2003. Stream inventory ieport Scott River watershed 2003. Report prepared for Siskiyou RCD.

Quigley, D. 2008. Scott River Watershed Monitoring Program – Water quality water temperature monitoring and sediment sampling and analysis 2005, 2006 & 2007. Siskiyou RCD, prepared for California Department of Fish and Game Agreement # P0410336.

Quinn, T.P. 2018. Behavior and Ecology of Pacific Salmon and Trout. 2nd edition. University of Washington Press. Seattle, WA.

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

Salo, E.O., W.H. Bayliff. 1958. Artificial and natural production of silver salmon (*Oncorhynchus kisutch*) at Minter Creek, Washington. Research Bulletin No. 4. Olympia, WA.

Scheuerell, M.D., and R. Hilborn. 2009. Estimating the freshwater component of essential fish habitat for Pacific salmon with the Shiraz model. Pages 187-202 *in* E.E. Knudsen and J.H. Michael Jr. (eds.) Pacific Salmon Environment and Life History Models: Advancing Science for Sustainable Salmon in the Future. American Fisheries Society. Bethesda, MD.

Simondet, J. 2014. Klamath River Basin 2014 Report to Congress. National Marine Fisheries Service. Arcata, CA.

SIT and WDFW (Skokomish Indian Tribe and Washington Department of Fish and Wildlife). 2010. Recovery plan for Skokomish River Chinook salmon. Submitted to National Marine Fisheries Service, August, 2010.

SIT and WDFW (Skokomish Indian Tribe and Washington Department of Fish and Wildlife). 2017. Recovery plan for Skokomish River Chinook salmon 2017 update. Submitted to National Marine Fisheries Service, December, 2017.

Snyder, J.O. 1931. Salmon of the Klamath River, California. Division of Fish and Game of California Fish Bulletin No. 34, California Department of Fish and Game, Sacramento, CA.

Som, N.A., N.J. Hetrick, R.W. Perry, and J.D. Alexander. 2019. Estimating annual *Ceratonova shasta* mortality rates in juvenile Scott and Shasta River Coho Salmon that enter the Klamath River mainstem. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Technical Report Number TR 2019-38, Arcata, CA.

Sommarstrom, S., E. Kellog, and J. Kellog. 1990. Scott River watershed granitic sediment study. Prepared for the Siskiyou County Resource Conservation District.

Soto, T., D. Hillemeier, S. Silloway, A. Corum, A. Antonetti, M. Kleeman, and L. Lestelle. 2016. The role of the Klamath River mainstem corridor in the life history and performance of juvenile coho salmon (*Oncorhynchus kisutch*). Report submitted to the U.S. Bureau of Reclamation, Klamath Area Office, Klamath Falls, OR.

SRWC (Scott River Watershed Council). 2006. Initial Phase of the Scott River Watershed Council Strategic Action Plan.

S.S. Papadopulos & Associates. 2012. Groundwater conditions in Scott Valley. Report prepared for the Karuk Tribe, Orleans, CA.

Steel, E.A., and 12 co-authors. 2009. Making the best use of modeled data: multiple approaches to sensitivity analysis of a fish-habitat model. Fisheries 34:330–339.

Sullivan, C.M. 1989. Juvenile life history and age composition of mature fall Chinook salmon returning to the Klamath River, 1984-1986. MS Thesis, Humboldt State University. Arcata, CA.

SWRCB (State Water Resources Control Board). 1979. Maps showing Scott River stream system diversions and irrigated lands. State of California, State Water Resources Control Board.

Taft, A.C., and L. Shapovalov. 1935. A biological survey of streams and lakes in the Klamath and Shasta National Forests of California. U.S. Bureau of Fisheries, Stanford University, Palo Alto, CA.

Taylor, E.B. 1990. Environmental correlates of life-history variation in juvenile chinook salmon, *Oncorhynchus tshawytscha* (Walbaum). Journal of Fish Biology 37:1-17.

Thamer, P. 2013. 2012 Monitoring report for the Scott River Water Trust. Callahan, CA.

Thamer, P. 2015. 2014 Monitoring report for the Scott River Water Trust. Callahan, CA.

Thompson, B.E., L.C. Lestelle, G.R. Blair, L.E. Mobrand, and J.B. Scott. 2009. EDT application in salmon recovery planning: diagnosing habitat limitations and modeling restoration action effectiveness. Pages 311-335 in E.E. Knudsen and J.H. Michael Jr. (*eds.*) Pacific Salmon Environment and Life History Models: Advancing Science for Sustainable Salmon in the Future. American Fisheries Society. Bethesda, MD.

Thompson, T.Q., M.R. Bellinger, S.M. O'Rourke, D.J. Prince, A.E. Stevenson, A.T. Rodrigues, … V.L. Butler. 2019. 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.

USFS (U.S. Forest Service). 2000. Lower Scott Ecosystem Analysis, Klamath National Forest, Scott River Ranger District, USDA Forest Service.

USFWS (U.S. Fish and Wildlife Service). 1960. A preliminary survey of fish and wildlife resources of northwestern California. U.S. Fish and Wildlife Service. Portland, OR.

USFWS (U.S. Fish and Wildlife Service). 1979. Hoopa Valley Indian Reservation inventory of reservation waters, fish rearing feasibility study, and a review of the history and status of anadromous fishery resources of the Klamath River basin. USFWS final report, Arcata, CA.

USFWS (U.S. Fish and Wildlife Service). 1998. Klamath River (Iron Gate Dam to Seiad Creek) life stage periodicities for chinook, coho and steelhead. U.S. Fish and Wildlife Service, Coastal California Fish and Wildlife Office. Arcata, CA.

Van Kirk, R.W., and S.W. Naman. 2008. Relative effects of climate and water use on base-flow trends in the lower Klamath Basin. Journal of the American Water Resources Association (JAWRA) 44(4): 1-18.

Wallace, M. 2004. Natural vs hatchery proportions of juvenile salmonids migrating through the Klamath River Estuary and monitor natural and hatchery juvenile salmonid emigration from the Klamath River Basin. July 1, 1998 through June 30, 2003. California Department of Fish and Game. Inland and Anadromous Sport Fish Management and Research, Klamath River Basin Juvenile Salmonid Investigations. Final performance report - Federal Aid in Sport Fish Restoration Act - Project No. F-51-R-6. Arcata, CA.

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

Warner, M.D., et al. 2015. Changes in winter atmospheric rivers along the North American West Coast in CMIP5 climate models. Journel of Hydrometeor, 16, 118–128. doi: http://dx.doi.org/10.1175/JHM-D-14-0080.1

West, J.R., 0. Dix, A. Olson, M. Anderson, S. Fox, and J. Power. 1990. Evaluation of fish habitat condition and utilization in Salmon, Scott, Shasta, and Mid-Klamath sub-basin tributaries, 1988/1989. Klamath National Forest, Yreka, CA.

Williams, R., editor. 2006. Return to the River: Restoring Salmon to the Columbia River. Elsevier Academic Press. Burlington.

Williams, T.H., E.P. Bjorkstedt, W.G. Duffy, D. Hillemeier, G. Kautsky, T.E. Lisle, M. McCain, M. Rode, R.G. Szerlong, R.S. Schick, M.N. Goslin, and A. Agrawal. 2006. Historical population structure of coho salmon in the Southern Oregon/Northern California Coasts evolutionarily significant unit. NOAA-TM-NMFS-SWFSC-390.

Williams, T.H., B. Spence, W. Duffy, D. Hillemeier, G. Kautsky, T. Lisle, M. McCain, T. Nickelson, E. Mora, and T. Pearson. 2008. Framework for assessing viability of threatened coho salmon in the

Southern Oregon / Northern California Coasts Evolutionarily Significant Unit. NOAA Technical Memorandum NMFS-SWFSC-432.

Yokel, E. 2006. Scott River summer habitat utilization study. Draft final report. Siskiyou RCD. Jobs in the Woods Project.

Yokel, E. 2008. Scott River Water Trust – 2007 summer flow leases -- habitat assessment. Prepared by the Siskiyou RCD for the Scott River Water Trust. Etna, CA.

Yokel, E. 2009. Scott River Water Trust – 2008 Monitoring Report. Prepared by the Siskiyou RCD for the Scott River Water Trust. Etna, CA.

Yokel, E. 2012. Scott River Water Trust – 2011 Monitoring Report. Prepared by the Siskiyou RCD for the Scott River Water Trust. Etna, CA.

Zimmerman, J. 2019. Drought, warming, and environmental flows: implications for native aquatic species. Presentation at the 2019 California Extreme Precipitation Symposium. https://cepsym.org/Sympro2019/Zimmerman.pdf