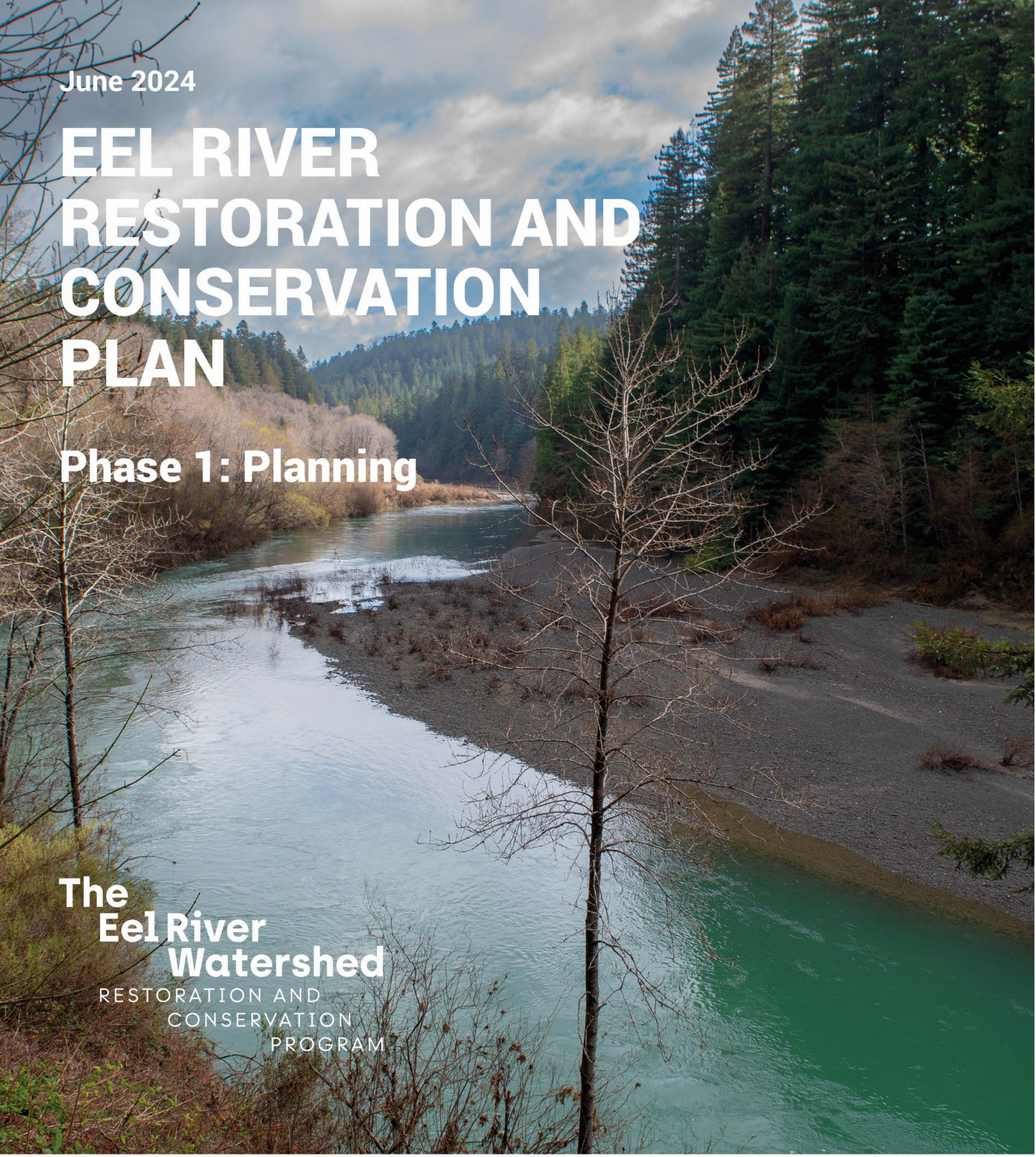
June 2024

EEL RIVER RESTORATION AND CONSERVATION PLAN

Phase 1: Planning



The Eel River Watershed
RESTORATION AND CONSERVATION PROGRAM

CALIFORNIA TROUT
FISH·WATER·PEOPLE

Stillwater Sciences

APPLIED RIVER SCIENCES

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

Suggested citation:
To be included for Final Plan

Front cover photo: South Fork Eel River
Credit: Gabe Rossi

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Acronyms and Abbreviations

AEAM	Adaptive Environmental Assessment and Management
AIC	Akaike information criterion
ANOVA	analysis of variance
ASP	Aquatic Survey Program
BLM	U.S. Department of the Interior, Bureau of Land Management
CalTrout	California Trout
CBG	Convention on Biological Diversity
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
DWR	Department of Water Resources
EDT	Ecosystem, Diagnosis, and Treatment
ESSA	ESSA Technologies Ltd
FACA	Federal Advisory Committee Act
FERC	Federal Energy Regulatory Commission
Forest Service	U.S. Department of Agriculture, Forest Service
GIS	Geographic Information System
HARP	Habitat Assessment and Restoration Planning
HUC	Hydrologic Unit Code
IFRMP	Integrated Fisheries Restoration and Monitoring Plan
IMW	intensively monitored watershed
LCM	life-cycle monitoring
NCRP	North Coast Resource Partnership
NGO	non-governmental organization
NHD	National Hydrography Dataset
NMFS	National Marine Fisheries Service
NRDC Coalition	Coalition of environmental NGOs led by Natural Resources Defense Council
PG&E	Pacific Gas and Electric Company
PIT	passive integrated transponder
Potter Valley Project	Potter Valley Hydroelectric Project
Plan	Eel River Restoration and Conservation Plan
Planning Team	

or Team	Team Responsible for the Preparation of the Eel River Restoration and Conservation Plan
Program	Eel River Restoration and Conservation Program
QA/QC	quality assurance/quality control
Reclamation	U.S. Bureau of Reclamation
RFP	request for proposal
RVIT	Round Valley Indian Tribes
SAB	Science Advisory Board
SHaRP	Salmonid Habitat Restoration Priorities
TAC	Technical Advisory Committee
TRRP	Trinity River Restoration Program
USFWS	U.S. Department of the Interior, Fish and Wildlife Service

ACKNOWLEDGEMENTS

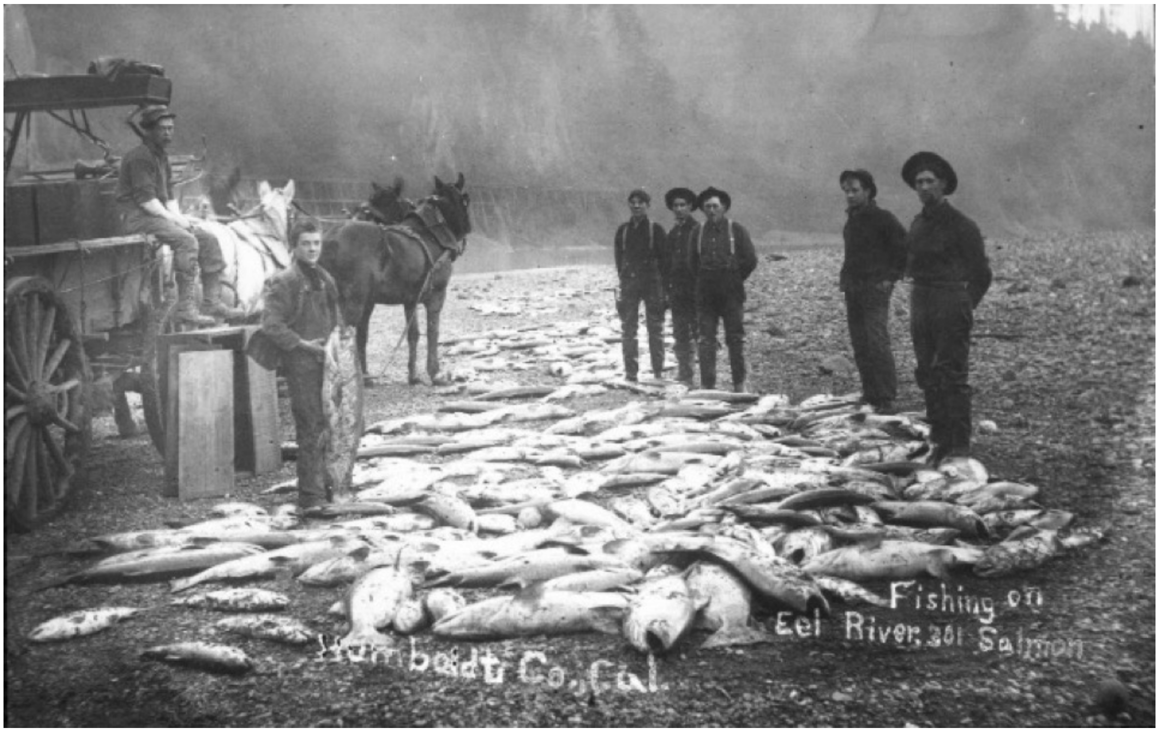
We would like to thank the following individuals and organizations for providing support for and input on various elements of the Eel River Restoration and Conservation Plan (Plan):

- Individuals on the Technical Advisory Committee (TAC), who participated in numerous meetings and workshops; reviewed interim products; and provided expert knowledge, data, and resources to support this effort (see Appendix A).
- Participants in Eel River Forum, including natural resources professionals and knowledgeable members of the public, who provided valuable input on restoration planning during meetings where the aspects of the Plan were presented and discussed.
- Representatives of Native American Tribes who provided valuable input and perspective on Tribal priorities for restoration and conservation of the Eel River watershed through participation in the Eel River Forum, TAC, or focused meetings. To date, we have received initial input from the Round Valley Indian Tribes, the Wiyot Tribe, and other tribal entities, and we are committed to further collaboration as the next phase of the Eel River Restoration and Conservation Program moves forward.

This Plan was funded by the California Department of Fish and Wildlife, from Governor Newsom's Executive Order N-10-21, which directed the CDFW to immediately implement projects that respond to drought conditions through habitat restoration.

PREFACE

> *There is at present no question of greater concern to the people of this county demanding immediate attention worse than that of the preservation of salmon in the waters of Eel River.*
>
> – Ferndale Enterprise (3 Feb. 1893)



There's a mythical, mystical feeling that comes from seeing a river's waters boil and churn from a large school of salmon making their majestic migration from the ocean into the river on their way to spawn. Chinook Salmon are the largest of the Pacific salmon, and each fish weighs 20 to 30 pounds on average and larger fish measure 36 inches or more, and often up to 48 inches! These enormous, powerful fish, having navigated the open ocean for several years, are seemingly even bigger in schools of hundreds on their journey inland to fight their way through currents and turbid storm runoff, up and over riffles and cascades, to eventually mate, and then die.

Great runs of migratory fish, like Chinook Salmon, transcend and unite cultures across time. They represent the life and health of watersheds and the human communities that depend on them. Even today, across the Pacific Rim, the arrival of salmon, of small silvery Eulachon (rru'mula'wi in the Wiyot language), called *salvation fish* by the lower Columbia River Tribes (MacKinnon 2015), and of the prehistoric jawless Pacific Lamprey is awaited with anticipation, prayer, and constant hope by humans and other resident fish-eaters (whales, sea lions, bears, otters, and riparian trees). They bring us food, medicine, and nutrients. To many of us, they also bring meaning, purpose, and identity. People say you need to go to Alaska to truly experience these annual spawning runs in all their grandeur, where salmon runs numbering in the tens-of-thousands persist. But it doesn't have to be that way.

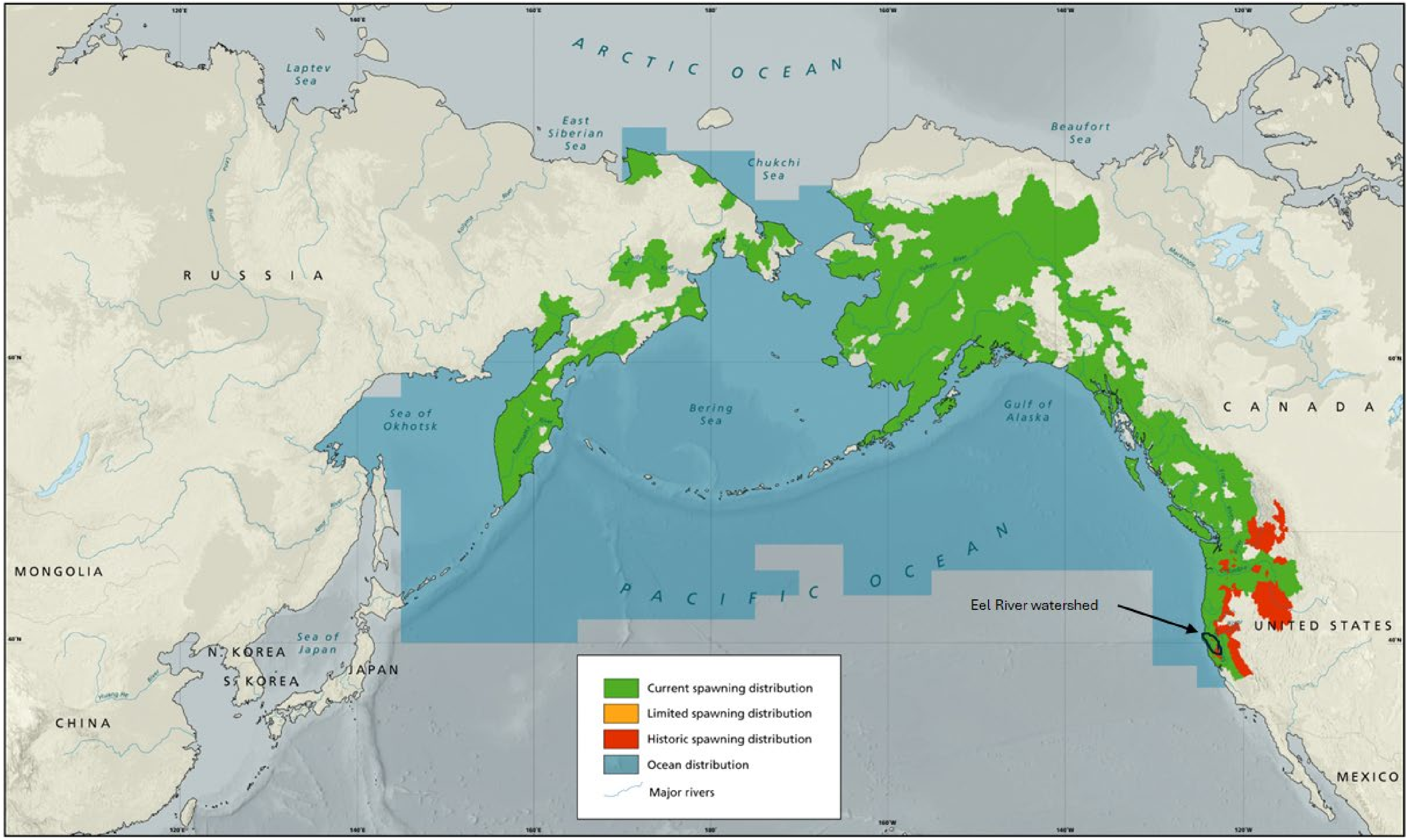
California *is* a salmon state and was once rich in salmon, steelhead, and anadromous fish abundance,[1] an abundance that has persisted for more than ten thousand years. The *State of the Salmonids II: Fish in Hot Water* (Moyle et al. 2017) stated: "Nowhere in the world is the diversity of salmonids…more evident than in California." Yes, California is at the southern end of the distribution of Pacific salmon (see figure below), but even at this end of their range, California's natural ecosystems once sustained populations of salmonids that ranked among the largest in the Pacific Northwest. At the top of that list were the incredibly abundant and diverse salmon and steelhead runs in the Central Valley's Sacramento and San Joaquin rivers, and the huge Chinook Salmon runs in the Klamath/Trinity River system. And then there was the Eel River.

The Eel River epitomizes everything about salmon in California. Lying at the heart of California's North Coast region, the Eel River spans five northern counties and 9,538 square kilometers and is ranked as the third largest watershed in California. The Eel River was misnamed by the first explorers (WW Elliot and Co. 1881) who mistook Pacific Lamprey as "eel" and called it the *Eel River,* yet the river has always been known as *Wiya't* by the Wiyot people since time immemorial.

The river has also been known as *The River of Abundance*, due to its highly productive fishery. In addition to copious runs of Pacific Lamprey, never estimated but surely numbering in the hundreds of thousands, the Eel River historically supported the third largest runs of salmon and steelhead in California, exceeded only by the Sacramento-San Joaquin and the Klamath rivers (CDFW 1972, as cited in Yoshiyama and Moyle 2010). In a 2010 study commissioned by CalTrout, UC Davis scientists estimated the historical run sizes from the early cannery records and concluded that combined runs of Chinook Salmon, Coho Salmon, and steelhead likely totaled more than a million adult fish annually in good years, of which there were likely many.

> *The Eel River basin once possessed significant populations of at least five distinct kinds of anadromous salmonids, including fall-run Chinook salmon, coho salmon, winter and summer steelhead, and coastal cutthroat trout. In addition, there were small populations of chum and pink salmon and possibly spring Chinook salmon. It is likely that an even greater number of seasonal runs or life-history variants within some species previously co-existed in the Eel River system.*
>
> – Yoshiyama and Moyle 2010

[1] The term *salmon* being used here refers to anadromous salmonids, the numerous species of salmon, steelhead, and trout.



Chinook Salmon distribution across the Pacific rim. The Eel River was a Chinook Salmon stronghold, near the southern end of their range but still at the heart of salmon country. (Map used with permission from the Wild Salmon Center)

Chinook Salmon were easily the most numerous of the Eel River's runs, given they don't require the whole freshwater capacity of the watershed year-round, but only borrow its ample mainstems and tributaries for half the year—the winter and spring seasons, and its estuary in the summer (Cannata and Hassler 1995), as they migrate out to sea as sub-yearlings (i.e., less than one year-old). According to Yoshiyama and Moyle (2010), Chinook Salmon likely numbered in the many hundreds of thousands, even up to 800,000 adult Chinook Salmon in a single spawning season: early cannery records "were converted into whole-fish equivalents (SEC 1998). The resulting catch estimates averaged 93,000 fish per year for the 35 years of record (1857–1921) with a peak number of 585,000 fish processed in 1877." Averages aren't entirely revealing; the peak numbers are more relevant, and those numbers only represent the fish that were actually caught, not those that "escaped" into the river to spawn. By 1854, immediately following the arrival of the first settlers to the Eel River in 1850, salmon were being packed in salt barrels and shipped throughout California and by 1857 were shipped as far as New York and China (Van Kirk 1996). Recorded harvests sometimes exceeded 16,000 fish in a single day, caught with gill nets in the estuary! Several times over the next decade, the Eel River's cannery output exceeded those of the Columbia River (Van Kirk 1996).

Similar data were used to estimate the two other dominant Eel River anadromous salmonid species—Coho Salmon and steelhead. For Coho Salmon, historical numbers of spawning adults were probably in the 50,000–100,000 fish per year range; winter and summer steelhead were likely 100,000–150,000 adults per year (combined). Indeed, the Eel River was nature's fish factory. Historically, the Eel River was remarkable for its complete dominance by anadromous fishes. Other native anadromous fishes in the Eel River included Coastal Cutthroat Trout, Pacific Lamprey, Green Sturgeon, Longfin Smelt, and the occasional anadromous Three-spine Stickleback. This incredible abundance of anadromous fish not only provided nutritious sustenance for indigenous peoples of the Eel River and early Euro-American settlers but also linked the freshwater ecosystem to a huge surplus of marine-derived nutrients imported inland in the form of salmon carcasses, salmon eggs, and even pelagic (planktonic) larvae—described as tiny protein snacks floating in deep, isotonic estuarine waters. Abundant runs of anadromous fish subsidize marine-derived nutrients into multiple trophic levels of riverine ecosystems, in which nutrients from salmon excrement, eggs, and carcasses can directly feed local scavengers, decompose to support bottom-up food webs, and enrich soils to fuel riparian vegetation. For example, Reimchen et al. (2003) showed that wood samples extracted from cores of ancient trees contained detectable levels of marine-derived nitrogen, and that marine-derived nitrogen levels in wood of trees were proportional to the numbers of salmon entering the streams. Kline et al. (1990) demonstrated that nearly 25% of nitrogen in the foliage of riparian vegetation in a southeastern Alaska stream is derived from marine sources.

But there was even more to what makes the Eel River abundance special. The Eel River has the highest recorded suspended sediment yield per drainage area of any river of its size or larger in the contiguous United States (1,720 ton per square kilometer per year according to Brown and Ritter 1971). The Eel River also has an enormous annual water yield: the mean annual discharge for the Eel River (i.e., the average volume of water flowing out of the Eel River watershed in a year) is approximately 5.8 million acre-feet. This enormous annual water yield places the Eel River among the highest water yield rivers in the state. The Eel River also boasts more Wild and Scenic River miles than any other river system in the West, with 398 designated miles on the mainstem, its three forks, and the Van Duzen River. Further, it hosts the largest surviving contiguous stand of old-growth redwoods in the world: the 10,000-acre Rockefeller Forest spanning the lower South Fork Eel River and the lower Bull Creek watershed has some of the tallest trees in the world, some of which are thousands of years old. Finally, the Eel River delta and estuary is the third largest estuary in California (CDFG 2010), covering approximately

33,000 acres; the estuary is designated as critical habitat for salmon and steelhead under the federal Endangered Species Act.

The bounty of the Eel River could not, however, withstand the onslaught of European-American settlers who migrated into the watershed beginning in 1850. And so, as with so many other rivers and salmon populations throughout California, in little more than 40 years humans had pushed these iconic species to the brink of extirpation. By 1893 the Eel River's abundance was nearly completely wiped out. A prescient letter published in the Ferndale Enterprise stated:

> *There is no mystery in the cause of the decline of the salmon. The fish have been mercilessly hunted, and the Cutting Packing Co.'s superintendent, Mr. Wetherbee, says there is no stream on the Pacific Coast that is fished as closely as Eel River.* ***He thinks that the salmon run for the Eel River is a thing of the past.*** *Salmon canning factories multiplied as long as there was a good profit in the business, but when the scarcity was first felt, instead of leading the fishermen to take measures to protect the fish, these factories only encouraged more strenuous efforts to take all that could be caught, and now there are none to catch.*
>
> *The laws we have to protect the salmon are entirely inadequate when enforced, and are by no means enforced.* ***Whether anything can be done for California streams or not is doubtful.***
>
> – Ferndale Enterprise (27 Jan. 1893)
> Letter from Lower Island, Cannery Section, Ed. Enterprise

More than 130 years later, this great concern persists. Despite these concerns, the Eel River salmon did come back, somewhat, eventually. Fish counts conducted at Benbow Dam on the South of the Fork Eel River from 1938 to 1975, the only solid fish abundance estimates from anywhere in the Eel River, documented adult Chinook Salmon, Coho Salmon, and steelhead runs averaging 11,000 to 17,000 fish annually before 1955, and in the 1960s Chinook Salmon were estimated to have averaged 56,000 spawners annually in the entire Eel River watershed (Moyle et al. 2017). But these runs crashed again in the mid-twentieth century following the advent of mechanized logging and the historical floods of 1955 and 1964 that caused extensive sedimentation and degradation throughout the Eel River watershed.

Overall, the current abundance of adult salmonid populations in the Eel River is now hovering in the 1% to 5% range of historical abundance (13,000–16,000 Chinook Salmon, 500–2,500 Coho Salmon). This historical decline has generally been linked to various causes. The *State of the Salmonids II: Fish in Hot Water* lists 15 factors that cumulatively contributed to the decline in anadromous fish: fire, logging, recreation, instream mining, hatcheries, major dams, agriculture, grazing, mining, estuary alteration, residential development, urbanization, harvest, alien species introductions, and transportation (Moyle et al. 2017). Nearly all these factors apply in some way to the decline of the Eel River's salmonid populations, some of them greatly so, especially commercial salmon harvest, logging, two Pacific Gas and Electric Company (PG&E) dams that block migratory access, extensive estuary alteration for dairy and cattle ranching, and the introduction of non-native fish species, most notably the Sacramento pikeminnow.

This story of rapid settlement, degradation, and salmon population crash has now been well documented, not just on the North Coast and the Eel River (NFMS 2014, 2016), but across California (Moyle et al. 2017) and the Pacific Northwest (e.g., Lichatowich 1999). The Eel River was no exception and did not escape the devastation of major extractive industries and rapid and extensive land use changes.

All Eel River anadromous fish are at risk. According to Moyle et al. (2017), the California Coast Chinook Salmon population is rated at *High* risk; the Southern Oregon and Northern California Coast Coho Salmon is rated at *Critical* risk; the Northern California winter steelhead is rated at *Moderate* risk, but the Northern California summer steelhead is rated at *Critical* risk; and the Coastal cutthroat trout population is rated at *High* risk (Moyle et al. 2017). Widespread anecdotal information suggests that Pacific Lamprey and Green Sturgeon populations are also fractions of their historical levels. The State of California lists Pacific Lamprey and Green Sturgeon (Northern Distinct Population Segment) as Species of Special Concern with Moderate and High levels of concern, respectively (Moyle et al. 2015).

We are thus at a major crisis in our certainty about these species' present and future persistence. These threats should not be ignored—there are broad implications for coastal communities and indigenous peoples who depended and continue to depend on these resources for sustenance and cultural food sovereignty.

Add to these alarming threats the contemporary disruption from a changing planet, already leaving its imprint throughout the Eel River and California, both in the form of natural disasters as well as in resource management responses:

- *Wildfire*: From 2015 to 2019, 18,210 square kilometers (km^2) burned in California, and in 2020 alone, another 17,000 km^2 were consumed by wildfire. Of this, nearly 5,000 km^2 were in the North Coast region, including parts of the August Complex Fire, the largest fire in California history. Wildfires threaten community health and safety, water quality, and biodiversity. In recent years, drought, pests, tree pathogens, and historical land management practices have made the region susceptible to large, intense fires.
- *Drought and Flood*: California has a typical Mediterranean climate with annual seasons with wet winters and dry summers. But recent rain and drought cycles have become much more extreme. The 2020–2022 drought was the driest 3-year period on record, breaking the old record set by the previous drought from 2013–2015. Following this epic drought period, winter rains, atmospheric rivers, and floods returned with a vengeance in 2022–2023 and 2023–2024, having swung the pendulum to the other extreme. Between October 2022 and April 2023, more than 30 atmospheric river storms battered California, in one of the wettest winters on record.
- *Commercial Fishing Closure*: In 2023, California Department of Fish and Wildlife closed the 2023 salmon fishing season in California due to low population estimates. This was the second time in recent decades that commercial and recreational fishing was entirely halted.

So, where do we go from here?

There are fundamentally important reasons for protecting these fish and for bringing them back to abundance. First, salmon support coastal livelihoods, feed forests and streams, and occupy a high position on our mantle of iconic Pacific Northwestern species, alongside the grizzly bear and California condor. Second, and no less importantly, these fish are intimately adapted to the cold, clean waters of our rivers and streams and, thus, represent the health of those aquatic ecosystems. Polluted and degraded rivers and watersheds undermine the health and well-being of salmonid *and* human populations. In other words, if salmon can thrive in abundance, it's *because* their rivers and watersheds are healthy ecosystems. Wherever available, salmon have also been a highly accessible and nutritious source of food—throughout history for indigenous people, as well as for our modern diets.

But there's a deeper and more resonant meaning to these fish—important socio-cultural contributions of salmon to the well-being of people who depend on them. The Eel River is the ancestral home of numerous Tribal groups, including the Wiyot, Yuki, and Eel River Athapaskan peoples, and is also now the home of other Native American Tribes that were forcibly moved to the area in the early twentieth century, mainly composing the Round Valley Indian Tribes. Justin and Black (2019) noted: "Salmon give reason and meaning to life in a very foundational sense, and teach children how to view the world from the lens of their cultural values." The Wiyot people speak of "eco-cultural restoration" and do not make a distinction between *ecological* and *cultural* when referring to the need to restore the Eel River. In short, scientists, planners, regulators, and salmon-loving citizens must ensure a more equitable and sustainable salmon future for the Eel River and for the entire state of California.

Remarkably, these fish are still coming back! The 2023–2024 Chinook Salmon count, recorded through the use of four underwater sonar cameras, may exceed 16,000 adult Chinook Salmon basin-wide, the largest count in perhaps a decade. Recovery is still possible. After an era of intensive, unregulated resource use, laws enacted beginning in the 1970s—the 1972 Clean Water Act and the Endangered Species Act; Forest Practice Act of 1973 and subsequent stringent reforms by the California Board of Forestry under the Anadromous Salmonid Protection Rules passed in 2009; and regulation of fishing including the Magnuson–Stevens Act of 1976, have all enabled populations to at least stabilize in recent decades, albeit at very low levels.

Fortunately, the Eel River watershed retains substantial potential for recovery.

While the proportion of private property ownership in the Eel River is high, most of the watershed is undeveloped. Here, the human population has grown at a very modest pace in the last several decades, but overall, the Eel River watershed has relatively low human population density. The North Coast region is projected to continue to grow (NCRP 2020); however, slower population growth rates are expected in the northern part of the region (including the Eel River watershed) due to its geographic isolation.

The Eel River's salmon and steelhead are wild fish, not hatchery raised, making the Eel River the largest wild fish watershed in California.

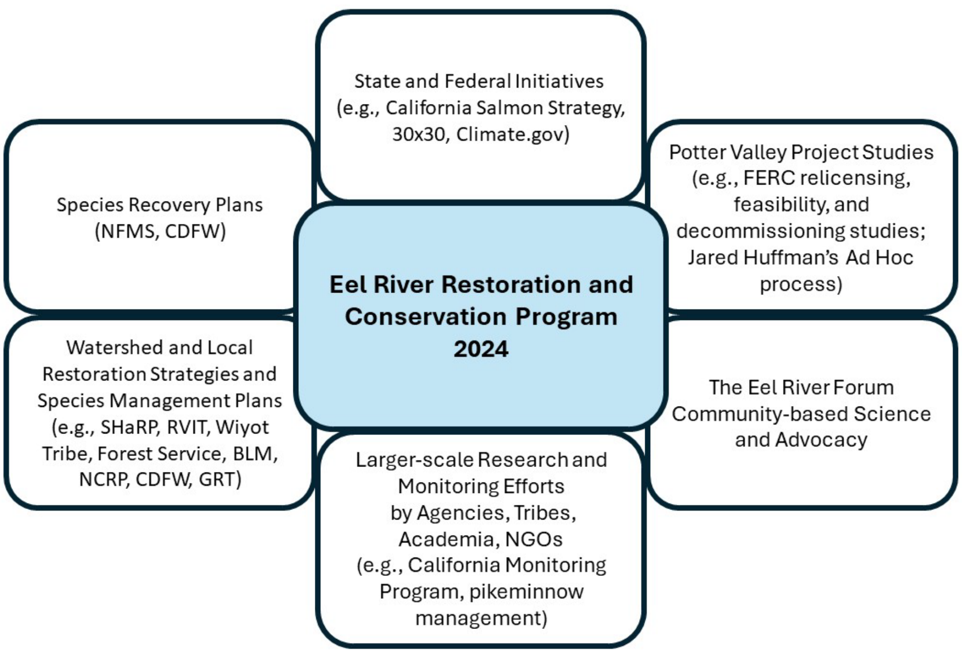
The Eel River watershed still shows signs of impairment from past logging practices and the floods of 1955 and 1964, but it has had 50–60 years to recover. Tributary watersheds have had time to reforest, and logging is now better regulated. Overall, the watershed recovery trajectory is positive.

Importantly, the Eel River *restoration community* has made enormous progress in restoring this watershed. Some "game-changing" restoration projects have been implemented in the last decade, and several more are slated for the next few years: the Salt River Ecosystem Restoration Project; the Eel River Wildlife Area—Ocean Ranch Unit Restoration Project; fish barrier removal projects on Bridge Creek, Woodman Creek, and Cedar Creek; the Eel River Estuary Preserve and Cannibal Island tidal habitat restoration projects, which are permitted and shovel ready; and Native American Tribes and scientists now taking up the challenge of managing the non-native pikeminnow population in the Eel River. Not to mention the countless other small and large restoration projects that have been tackled by the Eel River's numerous Native American Tribes, non-profit organizations, and grass-roots recovery groups (see following figure).

PG&E's Potter Valley Hydroelectric Project, located at the head waters of the Eel River, is now slated for decommissioning in the coming decade, potentially beginning as early as 2028 (PG&E 2023). PG&E's surrender of its project license, issued by Federal Energy Regulatory Commission, after 100 years of operation, and the proposed decommissioning, marks an opportunity to remove the only two dams—Scott Dam and Cape Horn Dam—on the Eel River and restore salmonid migratory access to the Eel River's headwaters and an estimated 288 miles of high-quality spawning and rearing habitat.

The Eel River is almost entirely free flowing, and with the decommissioning of the Potter Valley Hydroelectric Project proposed for 2028, the watershed will soon be entirely free of large dams. The decommissioning of PG&E's Potter Valley Hydroelectric Project also serves as an important catalyst for developing a watershed-wide restoration program and plan that can prioritize restoration and conservation actions and locations and for identifying and allocating financial and human resources (i.e., this Plan).

Finally, California's state agencies are committed to salmon recovery in the North Coast and throughout the state, as evidenced by the recently released Salmon Strategy (CDFW et al. 2024).



Eel River Restoration and Conservation Program. The Program is positioned to be at the center of salmonid and other anadromous fish recovery efforts that are ongoing since the 1997–2000 federal and state Endangered Species Act salmonid listings, including guiding planning, implementation, science and monitoring, and basin-wide coordination.[2]

[2] Acronyms are defined in the list of acronyms and abbreviations in the front matter of this Plan.

The decline in salmonid populations in response to the historical, contemporary, and ongoing stressors in the Eel River highlights the need for a holistic Eel River salmon recovery plan. In short, our generation will decide the fate of salmonid abundance in the Eel River. We have an opportunity to act now and plan for restoration, conservation, and resilience to future change. We must act now, in a holistic way, to restore these iconic anadromous fish populations in the Eel River and protect this enormously important watershed, before it’s too late. Our hope is for this Plan to set us on the path to recovering the River of Abundance.

EXECUTIVE SUMMARY

[To be provided for Final Plan]

1 INTRODUCTION

The history of the Eel River, as described in the *Preface*, demonstrates a clear need for immediate salmon recovery actions and a holistic watershed-wide restoration and conservation strategy. Furthermore, the upcoming decommissioning of Pacific Gas and Electric Company's (PG&E's) Potter Valley Hydroelectric Project (Potter Valley Project), arguably the largest conservation and restoration project conducted to date in the Eel River watershed, represents a catalyst for watershed-wide restoration. Aquatic habitats have been significantly impaired by past and recent intensive land use practices. These population declines have, in turn, resulted in state and federal listings to protect and facilitate recovery of these populations (Table 1-1) (CDFW 2014; NMFS 2014, 2016; Eel River Forum 2016). Given the current circumstances in the Eel River and its history, it is clear that the time is now to develop an Eel River Restoration and Conservation Plan and ensure the ecosystem provides for generations to come.

1.1 Eel River Restoration and Conservation Plan

An initial fisheries restoration framework for the Eel River watershed was developed by Stillwater Sciences and McBain Associates (2021) to build on the potentially transformational habitat and fish passage improvements anticipated by relicensing or decommissioning of the Potter Valley Project.[3] The 2021 framework has been refined herein to include three phases: (1) Planning, (2) Program Formation and Prioritization, and (3) Implementation, Monitoring, and Assessment (Figure 1-1). Leveraging this framework, California Trout (CalTrout) led development of Phase 1: Planning—the outcome of Phase 1 is this document, the Eel River Restoration and Conservation Plan (the Plan), which will lead to the execution of Phase 2 and Phase 3. In Phase 2, the Eel River Restoration and Conservation Program (Program) entity will be formed and include hiring Program directors, administrators, and staff. Phase 2 will also include implementing the prioritization process that will determine the areas and actions needed to effectively and efficiently restore the Eel River. In Phase 3, Program actions will be implemented and paralleled by a robust monitoring program to assess effectiveness of the Program (Figure 1-1).

This document describes the planning and development of the key Program components. This Plan was developed by a Planning Team that includes experts from CalTrout; McBain Associates – Applied River Sciences; Stillwater Sciences; and University of California, Berkeley. The Planning Team is supported by team members from the Round Valley Indian Tribes, The Wiyot Tribe, and a Technical Advisory Committee (TAC), composed of regional experts from agencies, universities and Tribes (see Appendix A for more information about the Planning Team and the TAC).

[3] At the time of the 2021 fisheries restoration framework development, the Potter Valley Project was still being relicensed by PG&E. Soon after the framework was completed, PG&E announced the abandonment of the Potter Valley Project. Approximately a year later, when no viable parties were able to take over the Potter Valley Project, PG&E initiated the decommission phase and is in its current state today.

Figure 1-1. Conceptual diagram of phases needed to establish the Eel River Restoration and Conservation Program. Phase 1: Planning describes the work that went into developing this Plan document.

The goal of the Plan and of Phase 1 of the Program is to develop products (e.g., data, presentations, documents) that build the groundwork and make recommendations to create a successful Program (Section 1.2). Building from the restoration framework (Stillwater Sciences 2021), the Plan moves through each task, develops products, and reviews them with a TAC and the Eel River Forum (see Appendix B for comments from the Eel River Forum). This peer-reviewed approach was selected because the success of the Program depends on support from state/federal agencies, non-profit organizations, Tribes, and all community members of the Eel River watershed.

The Plan includes the following steps:

1. Define Program vision and goals (Section 1.2.1)
2. Synthesize background information and spatial analysis framework (Section 2)
3. Develop species conceptual life-cycle models to identify potential limiting factors (Section 3)
4. Identify and categorize restoration and conservation objectives and actions (Section 4)
5. Develop a prioritization framework and approach (Section 5)

6. Develop a management and administrative framework and funding strategy (Section 6)
7. Develop a monitoring and adaptive management framework (Section 7)

In this Plan, the Planning Team shares the outcomes, frameworks, and recommendations from the preceding list of tasks. The first task was to develop the vision and goals of the Program, which are considered fundamental to its success and to gather support from the watershed community. The Planning Team investigated and compiled existing data on anadromous fish life-history needs, riparian area, land cover, and vegetation, among other data specific to the Eel River watershed. During this process, the Planning Team built a spatial framework and a data set of “Channel Archetypes” to represent groupings of distinct habitat types for fish use and restoration actions. The Planning Team also compiled a list of data gaps that can be addressed during future phases of the Program. Next, the Planning Team built a comprehensive list of potential restoration and conservation actions and framed these in a tiered objectives framework grouped by the following categories: Fish Populations, Habitats, Landscapes, and Conservation. These actions were further defined and categorized within the numbered Channel Archetypes to directly relate the actions to fish life-cycle history needs where appropriate. A prioritization framework was built to outline options for deciding on which sub-basins at the Hydrologic Unit Code (HUC) 12 level of granularity have the highest priority for restoration and conservation implementation. Finally, the Planning Team developed and then integrated the frameworks for implementing, monitoring, managing, and funding actions, which work in concert to ensure actions are accomplishing restoration and conservation goals and thus, resilience in the Eel River watershed. Each of these tasks was done with information sharing and feedback meetings with the TAC and the Eel River Forum.

1.2 Eel River Restoration and Conservation Program Overview

This section introduces the Proposed Eel River Restoration and Conservation Program (Program). Forward thinking and visionary, the Program is intended to guide and implement a substantial, collaborative, long-term restoration and conservation approach that revitalizes the Eel River and restores its fisheries. The Program is intended to be more than a document or an informal group; rather, the Program is intended to serve as an administrative entity that will guide and oversee restoration and conservation in the Eel River watershed. The Program is intended to focus on coordinating resources from agencies, Tribes, municipalities, and conservation groups all aligned with a similar vision: Restore the Eel River.

The Program’s three phases are not necessarily meant to be implemented sequentially, rather they can move in parallel and be complimentary of each other. For example, implementation and monitoring of projects requires prioritization to be complete (Phase 2 and Phase 3), rather these phases can happen simultaneously to demonstrate potential effectiveness. The Program is currently completing Phase 1, planning. Planning in this context refers to the development of the Program and its individual components that will ensure Program success; it is not planning specific actions. Program components will be implemented as the Program develops and evolves. For instance, during Phase 1, spatial data was compiled at the same time as specific species’ life-history models (which are intended to inform the prioritization of restoration and conservation actions) are developed. While prioritization is intended to take place during Phase 2, the road map or framework prioritization was developed in Phase 1.

The Program aims to take a holistic approach to restoring and conserving the Eel River watershed with a particular focus on the river corridor. To achieve the river corridor approach, the Planning Team selected a series of focal species—Chinook Salmon (*Oncorhynchus tshawytscha*), Coho

Salmon (*Oncorhynchus kisutch*), steelhead (*Oncorhynchus mykiss*), Pacific Lamprey (*Entosphenus tridentatus*) and Green Sturgeon (*Acipenser medirostris*)—that are the focus of the Program. The Program should not ignore the interconnectedness of the ecosystem and the indirect relationships that the riparian corridor and upslope processes can have on the focal species. In addition to restoration and conservation of aquatic habitats and the species that reside in those habitats, the Program must also address the continuous and ongoing threat of climate change to the Eel River and the need to develop climate mitigation strategies within the watershed. Finally, the Program must also partner with and be invested in the community members across the watershed and incorporate the ecosystems services that support those community members, such as recreational access, access to clean water, economic benefits, and a robust and harvestable fishery.

1.2.1 Program Vision and Goals

A primary objective of Phase 1 was to develop a framework for a successful Program and define its key components (Section 6). A clear vision statement and supporting goals are critical components of a successful long-term restoration program (Beechie et al. 2008). Therefore, the Planning Team developed the Program's vision and goals. The vision statement and goals will provide The Program guidance and strategies into the future and ensure the vision and goals continue to align with the community's values and intended outcomes for the Eel River. In crafting the Program's vision statement, the Planning Team combined the technical understanding of the ecosystem, community values, and the connections between the focal species and the habitat to support it. The vision statement and goals were reviewed by the TAC, and the Planning Team held community meetings (Eel River Forum) to review the vision and goals with regional experts and community members. The Planning Team also looked to restoration programs with successful results throughout the western United States to develop a vision statement that would be realistic, achievable, and inspire creative solutions to the issues in the Eel River.

1.2.1.1 Program's Vision Statement

A restored Eel River watershed that is composed of diverse and resilient habitats from headwaters to sea, self-sustaining and harvestable native fish, and healthy local communities.

The terms used in the vision statement and the rationale for their inclusion follow:

Restored Eel River Watershed:	*Definition:*	A restored Eel River watershed that remains healthy over time despite stressors from climate, land use, and natural disturbance. The term *restored* does not necessarily imply a return to unimpaired conditions, but a significantly improved condition that is informed by the state and function of unimpaired conditions.
	Rationale:	Restoration provides desired watershed benefits (described in the vision statement) over the long term for future generations.
Diverse Habitats:	*Definition:*	Habitats that vary across the watershed and differ in features (e.g., flood plain versus estuary) and function (e.g., food and fish production).
	Rationale:	Diverse habitats create numerous pathways for native fish to successfully complete their natural life cycle and are important for maintaining productive and resilient populations.

Resilient Habitats:	*Definition:*	Habitats that remain healthy over time and across the watershed, despite stressors from climate, land use, and natural disturbance.
	Rationale:	Resiliency provides desired habitat benefits over the long term and resists watershed productivity limitations across the watershed in response to natural and human-induced stressors.
Headwaters to Sea:	*Definition:*	Headwaters to sea encompasses the spatial extent of the Program, including estuarine habitats to the high-elevation headwater habitats.
	Rationale:	Achieving and sustaining significant watershed improvements requires integrated restoration and conservation actions over a wide range of habitat types and sub-watersheds throughout the Eel River, including headwaters, mainstems, and estuarine habitats. The term also refers to the connections needed for migratory fish to pass through the watershed and complete their life cycle.
Self-sustaining and Harvestable Native Fish:	*Definition:*	Self-sustaining native fish populations that are robust enough for harvest by recreational, commercial, and Tribal communities through time without requiring long-term hatchery supplementation or management intervention. Harvestable native fish include populations of Chinook Salmon, Coho Salmon, steelhead, Pacific Lamprey, and Green Sturgeon, and other species that exceed minimum adult escapement levels in the Eel River needed to produce numbers of juvenile fish that lead to successive harvestable adults.
	Rationale:	The ability to sustainably harvest native fish is important for healthy local communities as a food source, as well as recreational, commercial, traditional, and ceremonial uses.
Healthy Local Communities:	*Definition:*	Healthy communities that support all basic human needs, are socially connected, culturally vibrant, safe, environmentally sustainable, and economically secure.
	Rationale:	Local communities and Native American Tribes are integrally tied to the Eel River watershed, and thus, restoration and conservation actions support the sustainable resource use and human access to Eel River resources that also support healthy local communities.

1.2.1.2 Program Goals

Watershed restoration programs, including the Program proposed in this Plan (Section 6), depend on goals to guide program actions and evaluate the effectiveness of those actions. It is usually implicit that the purpose of watershed restoration is to achieve a state of ecosystem condition or health, but that condition is difficult to define by broad goals alone, such as population abundance or habitat area. Attributes such as *restored*, *resilient*, *diverse*, and *productive* can be quantified (e.g., with units) in some contexts. But these attributes also imply a qualitative meaning that emerges from shared understanding within the human community present in the system. Within any human community, there will be differences of opinion on the goals and desired outcomes of watershed restoration. However, collaboration, clear communication, and knowledge sharing (as occurred with the TAC for this Plan) can lead to elements of a shared ethos or understanding, which is a powerful mechanism for guiding restoration and conservation priorities. This Plan uses a tiered list of goals and objectives in Section 4 that transitions from broad, qualitative goals (e.g., restored, resilient, and diverse) to more specific, quantifiable objectives and sub-objectives that define specific attributes of a desired ecological condition (e.g., increase number of returning adults). These tiered goals and objectives were informed by TAC input and by via feedback from the Eel River Forum (a forum of Eel River community members that have an open dialogue about conservation issues).

The following two categories of Program goals are the result of that process and support the vision statement above and will guide development of the Program Management framework described in Section 6.

The following *outcome goals* describe components of the Program that are needed to successfully restore and conserve the Eel River:

1. *Restore*: Restore and conserve variable ecological and geomorphic processes that support diverse life-history strategies of native fish to increase population size and resilience.
2. *Protect*: Protect and conserve landscape connections between important riparian and upland habitats.
3. *Incorporate Ecological and Geomorphic Processes*: Embrace the variability in dynamic ecological and geomorphic processes at the sub-watershed scale and integrate across the sub-watersheds to create an interconnected mosaic of habitats that support the various life-history stages and strategies of focal species.
4. *Support Socio-economic Values*: Support local community and Tribal resource needs, economics, and recreational values of the watershed.
5. *Recommend Actions*: Recommend restoration and conservation actions that are implementable on a timescale, magnitude, and trajectory that will achieve efficient and meaningful improvements.
6. *Prioritize*: Implement a restoration and conservation action prioritization process that integrates watershed attributes with the needs of native fish and the habitats they rely on.
7. *Monitor and Assess*: Include a robust monitoring, assessment, and active management process that allows evaluation of measurable goals and restoration targets, and refinement of the Program.

The following *process goals* describe principles and strategies for developing the Program:

1. *Coordinate with Local Entities*: Coordinate with Tribes, agencies, and local communities to build support for restoration goals and strategies.
2. *Integrate Best Available Information*: Incorporate the best available information in the Eel River watershed by synthesizing existing data, input from experts, and species management plans within the watershed.
3. *Build in Lessons Learned*: Incorporate lessons learned from ongoing and past restoration/recovery efforts in the Eel River watershed, and from other similar basin-wide programs.
4. *Include Traditional Ecological Knowledge*: Incorporate Traditional Ecological Knowledge from the Tribes within the Eel River watershed to understand historical ecology, develop restoration and conservation strategies, and inform the prioritization process.

Developing the Program vision and goals was a fundamental first step of Phase 1. After the Planning Team developed the vision statement and goals, it received input and feedback from the TAC at coordination meetings, and from Tribes and community members during both virtual and in-person Eel River Forum meetings. The intent of this input and feedback process was to ensure that the fundamental direction of the Program was supported and reviewed by not only technical scientists and experts, but also the watershed community who will benefit the most from successful implementation of the Program.

1.2.2 Defining Restoration and Conservation

For the purposes of the Plan, the Planning Team uses the definition of *restoration* developed by the Society of Ecological Restoration[4] as the process of assisting or accelerating the recovery of an ecosystem that has been degraded, damaged, or destroyed. Restoration is distinct from conservation in that restoration attempts to retroactively repair already damaged ecosystems rather than take preventative and protective measures to avoid future damage to an ecosystem. Restoration does not imply that the ecosystem can be returned to an unimpaired historic condition; rather, it attempts to change the trajectory of a degraded ecosystem towards one that results in a significantly improved condition.

Similarly, *conservation* is defined for the purposes of this Plan as the preservation and management of landscapes, biodiversity, and natural resources that are currently in a highly functional ecological state and would benefit from protection from future impairments. This definition of conservation does not imply that restoration cannot occur within conserved lands. Conservation intends to protect ecosystems from future damage, preventing the need for future restoration, which is less expensive and impactful to the ecosystem (an ounce of prevention is worth a pound of cure).

1.3 Watershed Setting

The Eel River watershed is a large and diverse watershed; it receives snowpack in the headwaters and heavy rains in the coastal areas, there are tributaries in old growth redwoods along the coast and dry conifer forests further inland (Figure 1-2). The Eel River is inhabited by a rich and broad spectrum of fish and other aquatic species that have successfully adapted to the physical and hydrologic diversity that the watershed provides. This section provides an overview of the Eel River watershed, its environmental setting, and a brief description of its diversity.

1.3.1 Climate, Hydrology, and Geography

The Eel River is the third largest watershed in California, with a drainage area of more than 9,538 square kilometers (km^2). The watershed occurs in California's rugged northern Coast Range within Humboldt, Mendocino, Trinity, Glenn, and Lake counties. The watershed is composed of seven primary sub-watersheds: Lower Eel, Van Duzen, Middle Main Eel, North Fork Eel, South Fork Eel, and Upper Main Eel. The nearly 200-mile-long mainstem Eel River flows northwest from the high inner Coast Range (peak elevation 6,782 feet) to the Pacific Ocean near Ferndale.

Most of the Eel River watershed is characterized by a Mediterranean climate with cool, wet winters and warm, dry summers. Between October and April, precipitation typically falls as rain at lower elevations and as snowfall at the higher elevations of the inner Coast Range. The strong gradient in average annual precipitation from west to east across the watershed ranges from about 40 inches in the lower, western portions of the watershed to about 80 inches in the higher, eastern portions of the watershed. Precipitation varies significantly within a calendar year and across water years.

The Eel River annually discharges an average of 5.8 million acre-feet of water, making it one of the largest rivers in California (CDFG 2010). At the lower Eel River U.S. Geological Survey Scotia gage, the Eel River can range from a maximum daily average discharge of 648,000 cubic

[4] Available at: https://ser-rrc.org/what-is-ecological-restoration/.

feet per second (cfs) to a low of about 20 cfs. The Coastal Watershed Planning and Assessment Program provides a more detailed summary of the Eel River hydrologic and climatic characteristics (CDFG 2010).

A complex gradient of aquatic habitat conditions occurs across the seven primary sub-watersheds, ranging from cold and wet to hot and dry. The South Fork Eel River and its tributaries in the western portion of the basin, for example, are predominantly cold-wet tributaries that occur at lower elevation and are cooled by the Pacific Ocean. Tributaries in the Upper Eel River watershed and the Middle Fork Eel River watershed occur at the opposite end of the spectrum compared to the South Fork, experiencing more arid climates and intermittent streamflow fed by snowmelt. The Eel River delta and estuary occupies nearly 33,000 acres near the river's outlet to the Pacific Ocean, historically providing critical habitat for aquatic species and life-history diversity.

Figure 1-2. Overview of Eel River watershed.

1.3.2 Geologic and Geomorphic Controls on Aquatic and Riparian Ecosystems

Geology is one of the most important overarching factors in determining physical habitat diversity and, in turn, salmonid life-history diversity in the Eel River watershed. Different geologic terranes exhibit distinctively different *landforms* (e.g., hillslope, valley bottom, and channel), *surface processes* (e.g., production and transport of water, wood, and sediment that influence channel form), and *hydrologic responses* (i.e., surface water and groundwater interactions that influence functional flows). These geology-driven differences play a fundamental role in determining spatial and seasonal differences in fish habitat suitability, as well as suitability of a given location for implementing restoration and conservation actions.

The Eel River watershed occurs within the northern part of the Coast Range Geomorphic Province, where migration of the Mendocino triple junction and evolution of the San Andreas transform boundary imprinted a strong northwest trend in the drainage network. The watershed is predominantly composed of the Franciscan Complex, a deformed accretionary prism of sedimentary, metamorphic, and igneous rocks that were assembled in a subduction zone and accreted to the continental margin between the Late Jurassic and Miocene (Jayko et al. 1989, Ohlin et al. 2010, McLaughlin et al. 2018). The Franciscan Complex primarily consists of three structural belts that decrease in age from east to west: the Eastern, Central, and Coastal belts (Jayko et al. 1989) (Figure 1-3). The Eastern belt, the earliest of the three Franciscan belts, is composed of less disrupted rocks that have undergone more uniform regional metamorphism than in the Central and Coastal belts to the west (McLaughlin et al. 2018, Blake et al. 1967). Much of the mainstem Eel River downstream of approximately Cape Horn Dam drains the Central belt. The Central belt consists of a Late Jurassic to Middle Cretaceous mélange matrix enclosing large blocks and slabs of more resistant rocks (McLaughlin et al. 2000, 2018). The western-most portion of the basin is predominantly underlain by rocks of the Coastal belt Franciscan Complex and Yager Terrane. These rocks are predominantly fine-grained marine sandstone, argillite, and conglomerate of Pliocene to Late Cretaceous age (McLaughlin et al. 1994).

The three belts of the Franciscan Complex exhibit contrasting hillslope geomorphology and erosion processes. Hillslope geomorphology in the Eel River watershed can be generally characterized as "hard" or "soft" based on topography, morphology, and surface processes (Kelsey 1980, Muhs et al. 1987, Mackey and Roering 2011). The higher rock-strength in Coastal belt rocks in the western portion of the basin typically leads to "hard" hillslope geomorphology with steep, ridge-and-valley topography and well-organized drainage networks where erosion is dominated by debris slides, debris flows, and fluvial incision (Kelsey 1980, Kelsey et al. 1995, Stock and Dietrich 2006). Conversely, the weaker and finer-grained mélange of the Central belt typically forms "soft" hillslope geomorphology where large earthflow complexes and gullies result in hummocky topography with longer, low-gradient slopes and poorly organized drainage networks. More competent blocks within the mélange persist as erosion-resistant topographic highs (Mackey and Roering 2011, Roering et al. 2015).

Naturally high erosion and sediment transport rates in the basin are attributed to active tectonics, erosive geology, high seasonal rainfall, and intense winter storm events. Sediment delivery rates generally increase from upstream to downstream and from east to west within the watershed (Stillwater Sciences 2021; Mackey and Roering 2011; USEPA 1999a, 1999b, 2002, 2003, 2004, 2007). Widespread anthropogenic disturbance over the last 150 years has increased erosion and sediment delivery from hillslopes and unimproved road networks to stream channels, impairing instream habitat conditions throughout basin.

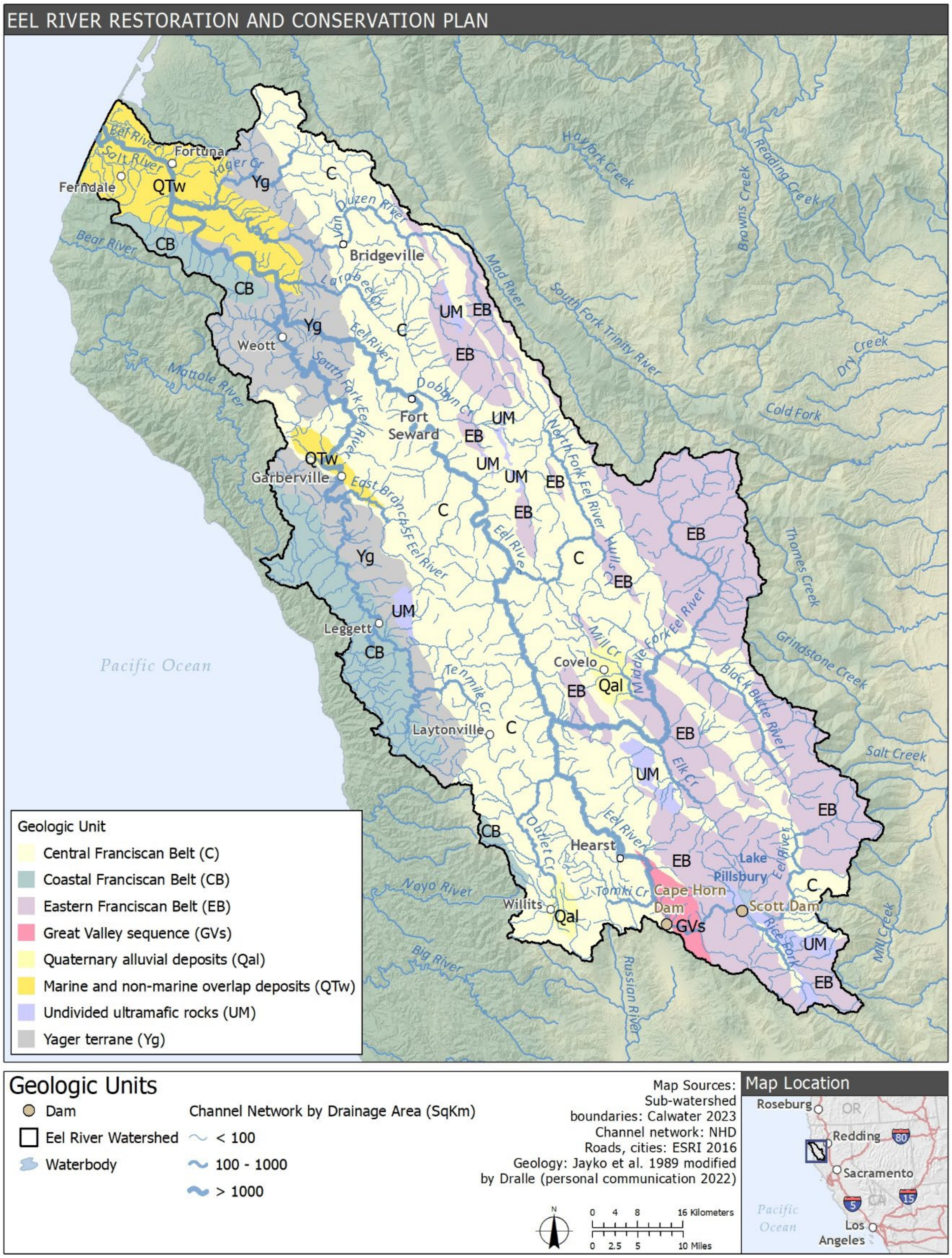


Figure 1-3. Simplified geologic map of Eel River watershed (Jayko et al. 1989, as modified by Dralle [personal communication 2022]).

Differences in bedrock geology and geomorphology across the three contrasting belts of the Franciscan Complex also result in distinctively different critical zone structure. The critical zone is the zone where chemical and physical weathering alter fresh bedrock, generating porosity and fractures capable of retaining and releasing water. Differences in the critical zone across the three contrasting belts of the Franciscan Complex result in unique hillslope groundwater dynamics (i.e., recharge, water storage capacity, and discharge) that strongly affect streamflow, temperature, and energetic regimes; with important consequences for aquatic and riparian ecosystem functions (Dralle et al. 2023) (Figure 1-4). Geology, geomorphology, sediment dynamics, and hillslope groundwater dynamics are therefore important factors in stratifying the Eel River watershed into sub-watersheds and channel archetypes that reflect key controls on fish life history, establishing restoration and conservation objectives, and developing decision support tools for prioritizing actions.

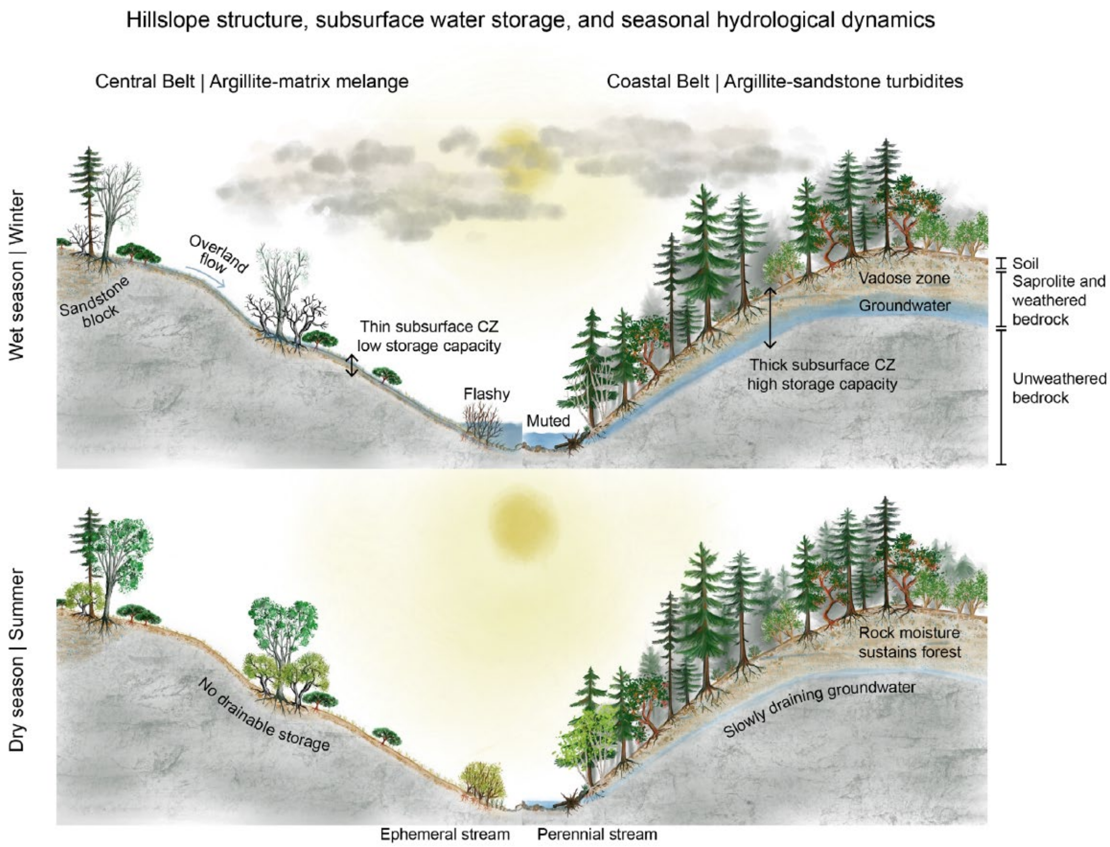


Figure 1-4. Relative comparison of hillslope structure, subsurface water storage, and seasonal hydrology between central belt (left) and coastal belt for wet season (top) and dry season (bottom) (used from Dralle et al. 2023 with permission).

1.3.3 Biodiversity and Ecological Setting

The watershed's physical diversity creates a template for a diverse and productive ecosystem. The canopy and vegetation of the Eel River is largely driven by underlying geology and lithology, and maritime influence. The coastal, foggy portion of the watershed is characterized by dense ferns and historically by tall conifers and redwoods. Inland, drier portions of the watershed are characterized instead by grassland savannas and oak woodlands.

Historically, the watershed supported at least four species of anadromous salmonids: fall-run Chinook Salmon, Coho Salmon, winter and summer run steelhead, and Coastal Cutthroat Trout (*Oncorhynchus clarkia clarkia*) (Yoshiyama and Moyle 2010). Within these species, there were likely many forms of diversity in habitat use and age structure that are not currently observed across the watershed (Section 3). Additionally, at least sporadic runs of Pink Salmon (*Oncorhynchus gorbuscha*), Chum Salmon (*Oncorhynchus keta*), and Eulachon (*Thaleichthys pacificus*) were likely (Yoshiyama and Moyle 2010). Pacific Lamprey provided the namesake for the river and was historically abundant, along with Green Sturgeon. Various other native fish species occupy the Eel River, including Sacramento Sucker (*Catostomus occidentalis*), Western Brook Lamprey (*Lampetra richardsoni*), Three-spined Stickleback (*Gasterosteus aculaeatus*), sculpin species (*Cottus* spp.), and occasionally, White Sturgeon (*Acipenser transmontanus*) (CDFG 2010). Introduced species include the widely distributed and abundant Northern Coastal Roach (*Hesperoleucus venustus navarroensis*), Sacramento Pikeminnow (*Ptychocheilus grandis*), as well as generally less common and less widely distributed species such as Largemouth Bass (*Micropterus salmoides*), American Shad (*Alosa sapidissima)*, Striped Bass (*Morone saxatilis*), Brown Bullhead (*Ameiurus nebulosus*), and sunfish species (*Lepomis* spp.).

The diversity of fish species and life histories are supported by a complex food web of aquatic plants and invertebrates. The composition and relative abundance of the food web members differ greatly between small, nitrogen-limited shaded tributaries and large, sunlight-rich mainstem rivers. In general, food webs become longer and more complex with increasing drainage area (Sabo et al. 2010), including in the Eel River (Power et al. 2013). In the sunny, mainstem rivers, the primary producer trophic level is dominated by the green, stringy mats of *Cladophera glomerata,* a filamentous green algal species (Power et al. 2008). *Cladophera* provide structure for other primary producers, including nutrient-rich, epiphytic diatoms like *Epithemia* that fuel invertebrate production and native fishes. *Epithemia*, which are not nitrogen fixers, become more common in drainages greater than 100 km^2, where there is also often a stepwise increase in nitrogen availability in the Eel River (Power et al. 2009). The inter-annual variability in composition and abundance of primary producers in the summer months interacts with the magnitude and duration of wintertime flow events. For example, in years when winter floods scour out and suppress the numbers of the armored caddisfly grazer, *Dicosmoecus*, filamentous algae can be more productive (Power et al. 2008). Alternatively, when winters with bed-scouring flows are followed by summers with extreme drought conditions and flow stagnate, *Cladophera* tend to rot earlier, to be replaced with toxic cyanobacteria (Power et al. 2015). Cyanobacteria do not provide the same structure for nutritious diatoms, creating a less productive food web for fish species, and in some cases providing a public health concern from the release of microcystins (Power et al. 2015, Bouma-Gregson et al. 2017).

In shaded tributaries, the primary producers are a thin biofilm of diatoms and filamentous algae, which is often not visible to the naked eye due to suppression by armored invertebrate grazers (McNeely et al 2007). These often-invisible primary producers provide the “hidden carbon” that fuels the food web, along with influx of terrestrial carbon. In tributaries, drifting invertebrates are seasonally abundant and fuel the growth of rearing salmonids (Rossi et al. 2022). Rearing salmonids in small tributaries can also be fueled by the dispersal of aquatic invertebrates from the mainstem that provide a dense seasonal subsidy (Uno and Power 2015). The frequency and seasonality of the mainstem-tributary linkages are understudied throughout the watershed but may provide a missing food source in salmon-producing tributaries.

One theme that holds true throughout tributaries and mainstems in the watershed is the high inter-annual variability in ecological interactions and processes. In Mediterranean-climate riverine systems like the Eel River, the only predictable feature is unpredictability, and there is meaningful variability among years in the frequency and magnitude of winter flows and the severity of dry conditions the following summer (Gasith and Resh 1999). For aquatic species, the timing of hydrologic events relative to the progression of their life cycle largely determines their success and abundance (Resh et al. 1988). As a result, the variability of the Mediterranean seasonality influences energy fluxes up the food web, from primary producers to invertebrates and fishes, and across space, between larger and smaller channels and their upland slopes (Power et al. 2013). This inter-annual and spatial diversity likely created a mosaic of habitats that fostered the persistence of a diverse and productive fishery in the Eel River.

1.3.4 Watershed History

Historical anadromous salmon and steelhead populations in the Eel River likely exceeded a million returning salmon and steelhead in good years but have been reduced to about 3,500 fish in recent years (Yoshiyama and Moyle 2010, Moyle et al. 2017, CDFW 2019). A decline of salmonid populations and other species (e.g., Pacific Lamprey and Green Sturgeon) in the Eel River has been linked to various causes, such as historical logging practices, catastrophic flooding and sediment loading from historical logging practice, and salmonid over-harvesting (Yoshiyama and Moyle 2010).

Before the arrival of colonial settlers, the Eel River watershed was inhabited by several Native American Tribes. These Tribes had deep cultural and spiritual connections to the river, providing them with sustenance, transportation, and a source of cultural identity. The Eel River was not only a vital resource for food and water but also played a central role in their cultural practices and ceremonies, highlighting the deep relationship between the Native American Tribes and the river ecosystem.

Since the colonial settlement beginning in the 1850s, the dynamic balance of the Eel River has been disrupted by numerous stressors. Starting in the late 1800s and early 1900s, salmon fishing supplied the local canneries; to meet the demand and fuel profits, the fishing pressure unfortunately was excessive and nearly ended the fishery. During the same period, clearcutting of the watershed's timber was happening; to support the timber industry, roads and railroads were cut into the landscape. The newly cleared areas, once hit with the catastrophic floods, resulted in excessive runoff and sedimentation. Ultimately, these issues of increased sediment supply, channel aggradation and simplification, loss of riparian vegetation, and reduced large wood recruitment, increased water temperatures, and altered hydrology. In addition to these widespread watershed impacts, the construction of the Potter Valley Project in the early 1900s blocked access to the upper Eel River to spawning and rearing salmonids, introduced non-native Sacramento Pikeminnow, and diverted water from an already low-flow system into the Russian River (Cooper et al. 2020, Fitzgerald et al. 2022). Sacramento Pikeminnow consume and compete with juvenile salmonids and are thought to be a challenge for salmonid recovery in the upper Eel River. (Brown and Moyle 1997, Reese and Harvey 2002, Nakamoto and Harvey 2003, PG&E 2017). These historical stressors over the last 150 years have resulted in many ecological consequences, perhaps most impactful, are the loss and degradation of fish habitat and introduction of non-native species.

As the twenty-first century arrived, a set of new stressors presented themselves to the Eel River and compounded with those already present. Like many areas of California and the western United States, climate change has resulted in warmer air temperatures and more intense/frequent periods of drought (Dai 2013, Dettinger et al. 2015). The effects of climate are already being observed as drought, and the Eel River watershed is experiencing low streamflow and more intense and larger wildfires.

The Eel River watershed has also long been a hotspot for cannabis cultivation in Northern California (Bauer et al. 2015) with many farms illegally diverting water to support the thirsty plants. While each farm individually does not extract significant amounts of water, the cumulative impacts of cannabis cultivation can result substantially lower summer and fall flows that can disrupt the Eel River's food webs (Power et al. 2015). Taken comprehensively, the Eel River is now a difficult place for self-sustaining fisheries. However, as discussed in the *Preface*, it does not have to be this way. The Eel River and the species that use it are resilient and can be recovered with the right set of restoration and conservation actions.

1.3.5 Present-Day Land Management and Conservation

The Eel River's land management and conservation status is as diverse as its habitats. The Northern California Coastal Mountain Range is a remote and rugged area, but much of the watershed is privately owned by timber companies and individual landowners. Other large tracts of land in the watershed are under federal control by the U.S. Department of Agriculture, Forest Service (Forest Service), and the U.S. Department of Interior, Bureau of Land Management (BLM); under state control by the California Department of Fish and Wildlife (CDFW) or Department of Parks and Recreation; or local control by the counties and municipalities. Native American reservation lands are also present throughout the watershed; the largest is for the Round Valley Indian Tribes and the Wiyot Tribe. The complexity of landownership will present challenges to the Program. Overall, the Eel River watershed is 57% private and 43% public lands. Protected areas make up 20%, and non-protected natural areas and working forests make up 19%, indicating there is potential to take conservation action on lands throughout the watershed that are in a somewhat natural state, but not yet protected (CNRA 2023) (Table 1-1, Figure 1-3).

Table 1-1. Land management calculated square kilometers and square miles within the Eel River watershed boundary.

Land Management in the Eel River watershed	Square kilometers	Square miles	% of watershed
Private	5,397	2,088	57
Non-private and public (merged)	4,138	1,598	43
Eel River watershed total	**9,535**	**3,686**	**100**
Breakdown of Non-Private and Public Lands			
Forest Service	2,858	1,103	30
Other state and federal (Department of Parks and Recreation, Natural Resources Conservation Service, Department of Natural Resources, and others)	467	180	5
U.S. Bureau of Land Management	427	165	5
Non-governmental organizations	288	111	3
Native American Tribes	97	38	1
Other (city and county)	2	0.8	0.02
Breakdown of Protected Lands and Non-Protected Natural Areas			
Protected lands and easements (Gap Analysis Project 1 + 2, CNRA 2023)[1]	1,939	749	20
Non-protected natural areas and working forests (Gap Analysis Project 3 + 4, CNRA 2023)[1]	1,850	714	19

[1] Gap Analysis Project 1+2 refers to existing protected areas with a management plan in place. Gap Analysis Project 3+4 refers to other natural areas, working lands, and forests that have state or federal management in place but are not protected as conservation lands (CNRA 2023). Other land management data were derived from CalFire Land Ownership data 2022. All data were analyzed for the Eel River watershed by CalTrout in 2024.

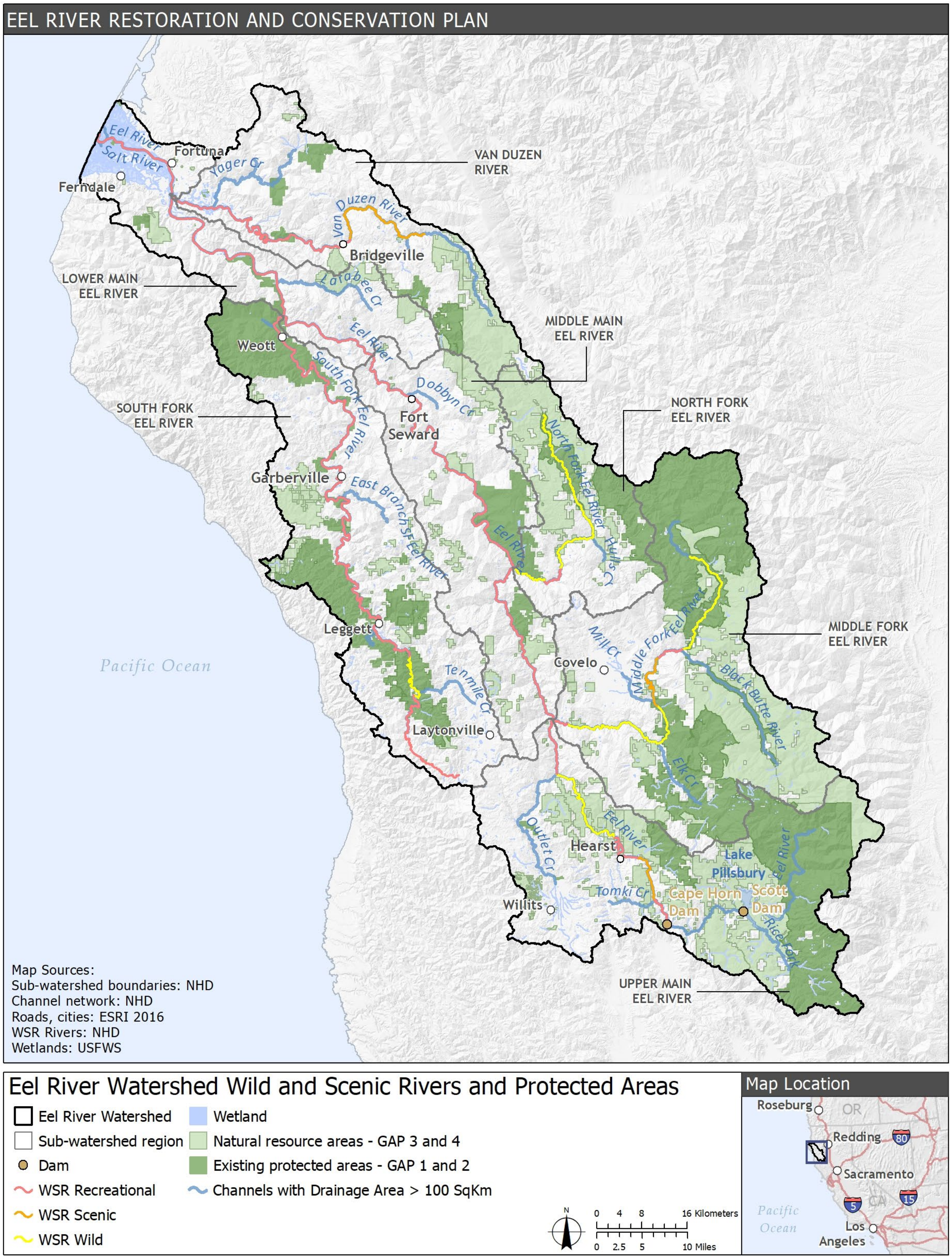


Figure 1-3. Wild and Scenic Rivers showing Recreation, Scenic, and Wild categories. Only parts of the Scenic and Wild designated areas have management plans, as described in Table 1-2.

A total of 431 linear miles of river corridors is designated as *Wild and Scenic*, specifically the Middle Fork Eel, North Fork Eel, and some smaller segments in the Van Duzen, South Fork Eel, and Upper Main Eel sub-watersheds (Figure 1-3). While protections under the Wild and Scenic River Act are beneficial, they are limited without a comprehensive protection effort to ensure resilience. At the time of this report, less than 14% of the Wild and Scenic segments in the Eel River watershed have a management plan. The current management plans for the Eel River Wild and Scenic Rivers are Scenic and Wild segments under Forest Service management. However, the buffer for the Forest Service segments of the Wild and Scenic River is derived from the center line, thus limiting the extent of the total area of the Wild and Scenic River, which is typically analyzed from the high-water mark on either side of the river Additionally, with the decommissioning of the Potter Valley Project, there is an opportunity to classify many river miles of the upper mainstem Eel River as Wild and Scenic River segments. Opportunities for improving the Wild and Scenic River system management are (1) establishing management plans for those areas lacking plans and (2) allocating new Wild and Scenic River segments (Table 1-2).

Table 1-2. Wild and Scenic River miles in the Eel River watershed separated by category and % of total miles per category without a management plan.

Category	Linear miles	Percent of total	Miles without a management plan	Percent without a management plan
Recreation	283	66%	283	100%
Scenic	36	8%	32	88%
Wild	112	26%	57	51%
Total	**431**	-	**372**	**86%**

Opportunities exist for improving the protected area with strategic conservation planning in the Eel River watershed. The opportunity described in this Plan combined with the intent of California's 30x30 initiative to protect 30% of lands supportive of biodiversity and climate resilience by 2030, point to the Eel River region as a target area for conservation that will restore the river's fisheries and build climate resilience at the landscape scale as intended by the 30x30 initiative.

2 SPATIAL ORGANIZATION FOR PLANNING

Restoration planning is best conducted at the watershed scale to incorporate linkages between biological and physical processes across spatial scales, from the hillslope to the channel, and from upstream to downstream (Wohl et al. 2005). All watersheds encompass variation in physical and biological characteristics, so, in restoration planning, there is a need to divide watersheds into units that match the scale of the process or structure of interest, and then piece it back together. The Eel River, as a very a large and diverse (5,794 km^2) watershed, is no exception. The Planning Team has developed a hierarchy of planning scales that enables organization and assessment of problems at smaller spatial scales, and then for the pieces to be reconnected and assessed the entire watershed. Here, the hierarchy of planning scales to be used in the Plan and in future prioritization activities (Section 5.2) is discussed in Section 2.1. The channel archetype scale, which is the smallest spatial scale that will be considered and was developed specifically for the Eel River, is then discussed in detail in Section 2.2.

2.1 Hierarchy of Planning Scales

Watersheds are inherently nested in space, from riffle-pool sequences, to reaches and sub-watersheds. The ecology and geomorphic form of a river at the smallest scale is affected by its position longitudinally in the watershed and the larger climatic and geologic setting (Vannote et al. 1980, Polvi et al. 2020). Additionally, while the day-to-day ecology of a fish depends on the habitat conditions in its current reach, many fish species, and especially anadromous fishes, use habitats throughout the watershed over the course of their life cycle. In places where restoration objectives include restoring ecosystem processes and the fishes that rely on them, river restoration planning is much more likely to be successful if undertaken at the scale of an entire watershed (Wohl et al. 2005). However, there is a need to develop data inputs and analyses that address smaller scales as part of the planning process. A hierarchy of spatial scales in the Plan will allow for the integration of datasets and analyses at different scales for analyses and prioritization.

Nested spatial scales will be used to organize data inputs, analyses, and planning efforts for this Plan, and is proposed for the Program when it is implemented (Figure 2-1). From big to small, the spatial organization moves from the whole watershed to seven primary sub-watersheds to HUC-12 sub-basins (large tributary basins, as defined by the National Hydrography Dataset (NHD), to the river segments (or reaches). Some analyses will also consider data inputs at the parcel level, which are typically smaller than the HUC-12 sub-basins. Underlying the spatial scales for planning are the geologic drivers of landscape processes described in Section 2.2. As such, geology is not a planning scale, but rather a structural organizational element that needs to be considered in concert with the nested planning scales.

The seven primary sub-watersheds are the Lower Eel, Van Duzen, Middle Main Eel, North Fork Eel, Middle Fork Eel, South Fork Eel, and Upper Main Eel sub-watersheds (Figure 2-1). This scale of representation is relevant for larger landscape processes such as dominant underlying geology, total annual precipitation, and maritime influence. As a result, these seven sub-watersheds differ in the (1) presence/absence of fish species (most numerous in the Lower Eel sub-watershed due to the inclusion of the estuarine environment); (2) unusual life-history strategies (e.g., presence of summer run steelhead in the Middle Fork Eel and Van Duzen sub-watersheds due to snowmelt hydrologic components); and (3) land use and resource management history.

Within the seven primary sub-watersheds, there are 113 HUC-12 sub-basins in the Eel River watershed. HUC-12 sub-basins are approximately 50 km^2 (range 26–104 km^2). The Plan considers HUC-12 sub-basins to be “ecological neighborhoods” because most include a collection of tributaries and mainstem river reaches that juvenile rearing salmonids could feasibly move between. HUC-12 sub-basins within a sub-watershed can differ in the geomorphic form of channels, temperature characteristics, and flow regimes. The HUC-12 sub-basins within a sub-watershed will be characterized for the potential need for restoration during the prioritization process in Phase 2 of implementing the Program (Section 5.2).

The next smallest scale of spatial organization in the Plan is county parcels. County parcels will be considered primarily for conservation planning, where land ownership is a driving variable. There are 44,642 county parcels in the Eel River watershed, spanning five counties and ranging significantly in size, from 0.000005 km^2 to 14 km^2 (Figure 2-1). Parcel-level planning and prioritization is needed to connect high-quality habitat or core parcels, integrate landowner support by initiating new or improved conservation easements on private land, and coordinate with agencies for conservation opportunities on public lands.

The final spatial scale of consideration in the Plan is channel segments, which are 1 km or less in length and are defined by the NHD and in some cases further divided (following FitzGerald et al. 2022). These channel segments are relatively uniform in geomorphic form, temperature, and flow regimes. Ecologically important features within these segments may be missed in this watershed-wide Plan (e.g., unique deep pools, or thermal refugia at tributary confluences). Understanding geographic variation in channel segments at a level of detail at < 1 km will be left to local practitioners who develop site-specific restoration and conservation actions. In developing the spatial structure for the Plan, the Planning Team identified a need to characterize commonalities between channel segments, which results in a set of “channel archetypes.” This clustering analysis was novel for the Eel River, and the goals and process are described below in detail (Section 2.2).

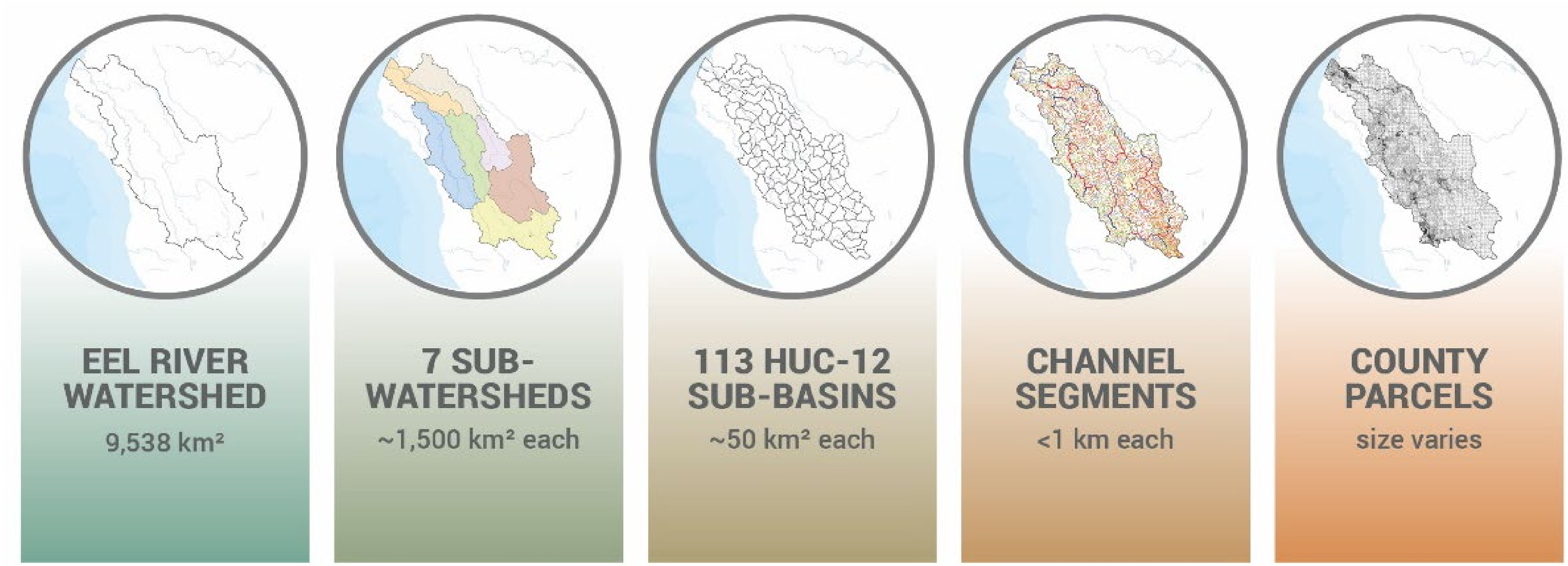


Figure 2-1. Planning scales used for restoration and conservation in the Eel River watershed. Eel River watershed boundary (n=1), primary sub-watersheds (n=7), HUC-12 sub-basins (n=113), channel archetype stream segments (n=10,541), county parcels (n=44,642).

2.2 Channel Archetypes

Habitat diversity within watersheds creates life-history diversity of fish species (Beechie et al. 2006, Lisi et al. 2013). A mosaic of diverse habitats allows fish to move between them, even if some habitats are seasonally unsuitable, and increases opportunities for growth and survival (Armstrong et al. 2023) (Figure 2-2). Because of the importance of life-history diversity for the stability and resiliency of fish populations (Hilborn et al. 2003, Section 3.2.2), the Planning Team sought to characterize channel diversity within the Eel River watershed as a way of predicting how many and what life-history strategies may have been historically present across the landscape. The channel archetype analysis is a grouping analysis that seeks to categorize habitat diversity for fish as driven by underlying geology (Section 2.3) for use in predicting fish use and designing restoration actions.

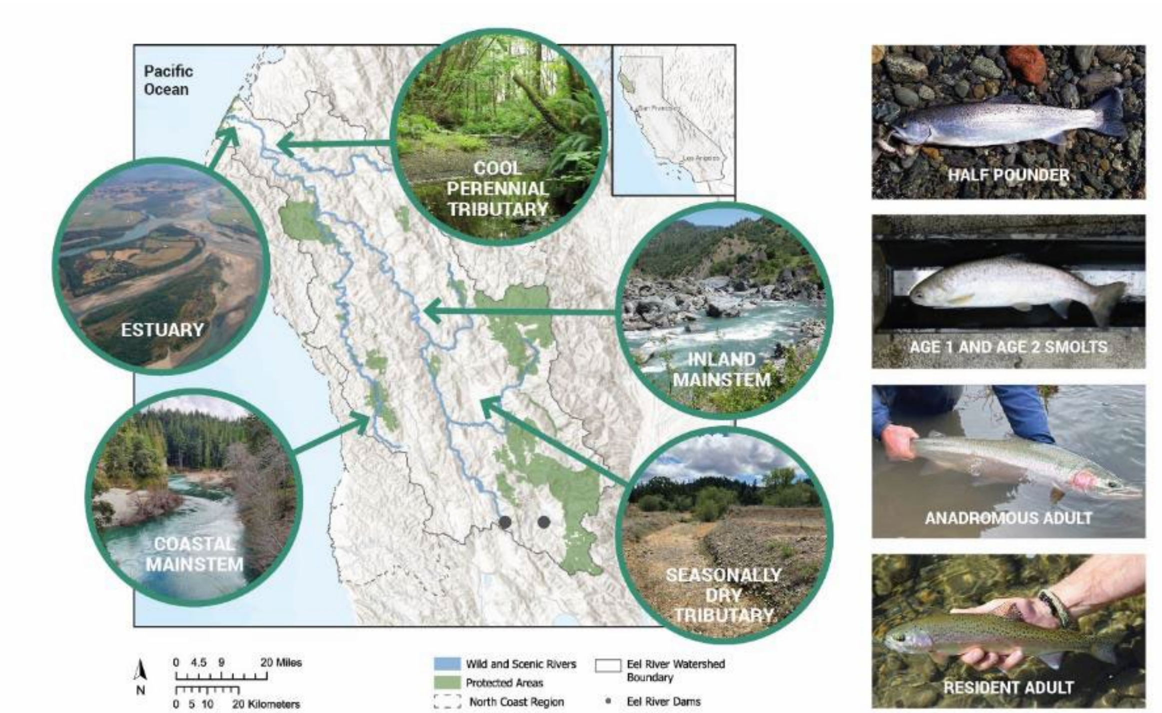


Figure 2-2. Diversity in stream channel characteristics, from cool tributaries to inland mainstems, provide a mosaic of habitats that differ in timing and extent of ecological productivity. This habitat diversity likely gave rise to life-history diversity, such as variation in the age at outmigration to the ocean or return to freshwater, within the native anadromous fishes of the Eel River. Categories of diverse habitat types, or *channel archetypes*, were developed for use in the Plan.

Channel archetypes were developed to categorize similar river channel segments across the watershed at the reach-scale (approximately 1 km) based on primary physical and environmental attributes that reflect physical processes and disturbance mechanisms that work to maintain channel morphology over time. These attributes influence (1) how fish use these channel segments and (2) the opportunities and constraints for restoration and conservation actions. The archetypes were designed to be a tool to help predict, in a spatially explicit manner, which streams throughout the watershed would support which life-history strategies for the focal species. Predictions of life-history diversity can then be linked to which restoration actions will be most appropriate and effective within the same river channel segments. The combination of predictions for potential life-history diversity value and restoration actions at the channel level will be used in the prioritization process described in Section 5.2.

Channel archetypes were developed using a hierarchical categorization of readily available, watershed-wide datasets on drainage area, channel slope, and stream thermal regime. See Appendix C for a more detailed overview of this process and the data inputs. These datasets represent many geomorphic categories that are likely to influence fish use and restoration potential. Drainage area and channel slope were calculated by FitzGerald et al. (2022) from NHD Plus. Mean monthly water temperatures were also predicted by FitzGerald et al. (2022) using a large-scale, empirically based statistical interpolation method named the Stream Spatial Network. The channel archetype analysis resulted in 14 groupings organized around drainage area, channel slope, and stream thermal regimes (water temperatures) (Table 2-1).

Table 2-1. Channel archetypes and the encompassing drainage area, slope, and thermal groups. The range of mean May and August water temperatures is shown to highlight that cool and warm channel archetypes can be seasonally suitable, and even more optimal, for salmonid growth.

Channel archetype	Code	Drainage area category	Channel slope category	Stream thermal category	Mean August water temperature range (°C)	Mean May water temperature range (°C)
Small tributary	0	Small tributary (<2 km^2)	All	Cold, cool, warm	8.3–23.3	6.5–21.2
Low-gradient, cold tributary	1.1-cold	Tributary (2–100 km^2)	<2%	Cold	11.5–17.0	8.9–15.4
Low-gradient, cool tributary	1.1-cool			Cool	17.0–20.0	9.7–16.4
Low-gradient, warm tributary	1.1-warm			Warm	20.0–23.3	11.4–16.5
Mid-gradient, cold tributary	1.2-cold		2–7%	Cold	11.6–17.0	7.4–15.3
Mid-gradient, cool tributary	1.2-cool			Cool	17.0–20.0	9.3–16.6
Mid-gradient, warm tributary	1.2-warm			Warm	20.0–22.3	12.3–15.3
High-gradient, cold tributary	1.3-cold		7–12%	Cold	10.4–17.0	7.5–15.2
High-gradient, cool tributary	1.3-cool			Cool, warm	17.0–21.8	10.5–15.5
Very high gradient tributary	1.4		>12%	Cold, cool, warm	8.3–20.9	6.8–14.9
Cool mainstem	2-cool	Mainstem (100–1,000 km^2)	<2%, 2–7%	Cool	14.7–20	9.7–15.9
Warm mainstem	2-warm		<2%, 2–7%	Warm	20–23.8	10.6–16.6
Large mainstem	3	Large mainstem (>1,000 km^2)	<2%	Cold, Cool, Warm, Hot	16.2–24.6	12.4–16.1
Estuary	4	Estuary	<1%	-	-	-

Notes: °C = degrees Celsius
km^2 = square kilometers

The channel archetypes have several limitations due to the methods and data used to develop the groupings. Some of the archetypes encompass a diversity of channel features and habitat types. For example, the estuaries encompass many different habitat types (e.g., Simenstad et al. 2011) that are not addressed in this Plan. Additionally, with any grouping analysis, outliers are lumped rather than highlighted. These outliers may be of outsized ecological importance (e.g., the large mainstem channels that are cold are not identified as a separate group due to their rarity). A separate analysis to identify unique habitats/channels may be warranted in the prioritization process, particularly if they have high ecological relevance (e.g., a biological hotspot).

Additionally, the archetype datasets likely do not encompass the true complexity of each variable due to their scale. For example, slope is calculated over 1 km segments, which is not suitable for identifying knickpoints or shorter low-gradient features within those segments. Similarly, the water temperature model does not predict thermal complexities of the river (e.g., stratified deep pools, or tributary confluence plumes), so potentially unique/anomalous locations within the river continuum will not be captured. Any recommended restoration and conservation actions linked to these channel archetypes are considered general guidelines. A necessary next step before undertaking a restoration project within a channel archetype would be to ground-truth the channel to determine project location and site suitability.

In summary, the hierarchy of planning scales described in this chapter, ranging in size from small channel segments and parcels to the entire watershed, will allow for nimble assessment of structure and processes across spatial scales. These spatial scales can be used to describe the nested habitat diversity that gives rise to fish life-history diversity, which is a critical component of the Plan (Section 3.2.2).

3 FOCAL FISH SPECIES CHARACTERIZATION

This section describes the rationale for using focal fish species as a foundation of restoration and conservation in the Eel River watershed; summarizes the approach applied to characterize each species and their potential life-history diversity through conceptual models (Appendix D); and outlines how the conceptual models can be used to inform restoration and conservation actions (Section 4) and aid in development and implementation of informed prioritization (Section 5) and monitoring frameworks (Section 7).

3.1 Rationale for Focal Species

A principal goal of the Program is to protect and aid in the recovery of native, anadromous fish species with commercial, recreational, or Tribal cultural value, as well as those with state or federal special-status designations (Section 1.2.1.2). Accordingly, the Planning Team selected fall-run Chinook Salmon, Coho Salmon, steelhead (summer- and winter-run), Pacific Lamprey, and Green Sturgeon as focal species for restoration and conservation (Table 3-1, Figure 3-1). Each of these species are high priorities for population recovery and management in the Eel River watershed (CDFW 2004; NMFS 2014, 2016; Moyle et al. 2015; Eel River Forum 2016; McBain Associates 2017; Wiyot Tribe Natural Resources Department and Stillwater Sciences 2016; Stillwater Sciences and Wiyot Tribe Natural Resources Department 2017; South Fork Eel River SHaRP Collaborative 2021).

Table 3-1. Focal fish species for the Eel River Restoration and Conservation Program and their special-status designations.

Common name *Scientific Name*	Federal and State status[1]	Rationale for inclusion
Chinook Salmon California Coastal ESU (fall-run) *Oncorhynchus tshawytscha*	FT, SSC[2]	Federal listing; Tribal importance; commercial and recreational fisheries; primary marine subsidy and ecosystem structuring species, represent large river and estuarine habitats
Coho Salmon Southern Oregon/Northern California Coast ESU *Oncorhynchus kisutch*	FT, ST	Federal listing; Tribal importance; historical commercial and recreational fisheries; represent cool and low-gradient streams, off-channel, and estuarine habitats
Steelhead (summer, fall, and winter runs) Northern California Coast DPS *Oncorhynchus mykiss*	FT, SE[3], SSC[2]	Federal and state listing; recreational fishery; Tribal importance; wide distribution across diverse coastal and inland habitats
Pacific Lamprey *Entosphenus tridentatus*	SSC, BLM, Forest Service	Tribal importance; unique ecological roles; important marine subsidy, wide distribution and long freshwater and ocean residence periods
Green Sturgeon (Northern DPS) *Acipenser medirostris*	FSC[4], SSC	Tribal importance; historical recreational fishery; represent large river and estuarine habitats

[1] Status designations are from Moyle et al. (2015) and CNDBB (2024). FT = Listed as Threatened under the federal Endangered Species Act; FSC = Federal Species of Concern; ST = Listed as Threatened under the California Endangered Species Act; SE = Listed as Endangered under the California Endangered Species Act; SSC = CDFW Species of Special Concern; BLM = Listed as Bureau of Land Management Sensitive Species; Forest Service = Listed as Forest Service Sensitive Species in Region 5.
[2] Moyle et al. (2015) lists the population as an SSC, but CNDBB (2024) does not.
[3] SE designation applies to summer-run steelhead only
[4] FSC designation from NMFS (2006).

Figure 3-1. Focal fish species for the Eel River Restoration and Conservation Program.

Importantly, the focal species collectively exhibit life-history strategies that use diverse aquatic habitats across the Eel River watershed. Restoring and conserving these habitats, as well as the physical and ecological processes needed by the focal species across their life cycles, effectively provides an umbrella of restoration and protection for other native aquatic and riparian species in the Eel River watershed (Lambeck 1997). For example, focusing on Chinook Salmon and Green Sturgeon requires understanding, restoring, and conserving habitats along the mainstem Eel River corridor, larger tributaries, and the estuary. A focus on steelhead and the wide range of adult and juvenile life histories displayed by the species ensures that channels in inland, higher elevation, and steeper parts of the watershed, as well as coastal-oriented and estuarine areas, are considered in planning and prioritization.

Other ecologically important aquatic species would also benefit from more focused attention, and their inclusion could contribute to more holistic watershed restoration planning; however, selecting too many focal species can defeat the purpose of a focal species approach by overcomplicating prioritization or spreading limited resources too thin. Still, additional focused assessments of important fish and aquatic wildlife species such as Longfin Smelt, Coastal Cutthroat Trout (whose southern distribution terminates at the Eel River), and Foothill Yellow-legged Frog, would be valuable to understand whether habitat needs for these species are not covered under the umbrella of the selected focal species. Information from these assessments could be integrated into future restoration planning, prioritization, and monitoring decisions.

3.2 Species Descriptions and Life-history Conceptual Models

This section explains the purpose of focal fish species descriptions and life-history conceptual models (Section 3.2.1), discusses the importance of life history and habitat diversity to fish population recovery (3.2.2), describes the approach used for developing life-history conceptual models for focal species (Section 3.2.3), and summarizes key outcomes of the conceptual models (Section 3.2.4).

3.2.1 Purpose

Identifying and prioritizing restoration and conservations actions that address the root causes of decline and most directly contribute to the recovery of focal species populations requires a thorough understanding their distribution, life-history timing, habitat needs, ecological interactions, and, most importantly, the factors driving their population dynamics. As described in Section 3.2.2, a fundamental component of anadromous fish abundance and resilience to environmental change is life-history diversity, or variation in how animals balance trade-offs among survival, growth, and reproduction (Roff 1992, Schindler et al. 2010). This Plan emphasizes one aspect of life-history diversity: the variation of movement patterns and habitat and resource use across time and space that individuals can exhibit over their life cycle. Accordingly, for each focal species, the Planning Team (1) reviewed and synthesized available information on each life stage and (2) developed life-history conceptual models to help identify and describe the suite of life-history pathways, their potential to exist in the Eel River watershed, and factors limiting their prevalence. The primary objectives of these efforts and their nexus with other parts of the Plan are listed in Table 3-2 and described in more detail in the sections that follow. The outcomes of these efforts for each species are provided in Appendix D.

Table 3-2. Primary objectives of focal fish species characterization and life-history conceptual models.

Objective	Restoration planning nexus
Describe population status, known current and historical distribution, ecology, life-history timing, and habitat needs for each life stage	Reference for all planning tasks
Identify and describe life-history strategies currently and intrinsically supported by the watershed and the factors limiting their expression[1]	Restoration and conservation actions (Section 4) Prioritization framework (Section 5) Monitoring and assessment framework (Section 7)
Systematically identify key stressors that limit population abundance and resilience by impairing habitat capacity, growth, survival, and life-history diversity	Restoration and conservation actions (Section 4) Prioritization framework (Section 5)
Identify important data gaps and generate testable hypotheses for factors limiting life-history expression and abundance for each species	Monitoring and assessment framework (Section 7)
Provide input and guidance on prioritization decisions	Prioritization framework (Section 5)
Develop basis and parameters for quantitative life-cycle models or other future models	Potential future quantitative tools to support prioritization

[1] In this Plan, the term *life-history strategy* refers to fundamentally unique life-history types within a species' life stage. For juveniles, tactics are generally defined based on length of time spent rearing in natal streams (e.g., natal rearing, spring fry emigrant, fall parr emigrant). The term *life-history pathway* is used to refer to the variation in movement patterns across time and space that can occur within a strategy. For example, within the spring fry life-history strategy of juvenile Coho Salmon, there are different pathways that rear for varying amounts of time in some combination of mainstem corridors, non-natal tributaries, and the stream-estuary ecotone.

3.2.2 Importance of Life-history Diversity and Habitat Diversity

Within a population of fish, especially highly migratory species, different individuals can exhibit different patterns of movement across space and time during their life cycle. The diversity of pathways that can occur from the time of birth in spawning streams until fish enter the ocean and ultimately return to spawn in fresh water is commonly known as life-history diversity. Like a diverse financial portfolio, having a diverse portfolio of life-history strategies in a fish population spreads the risk of mortality across time and space, contributing to resilience and reducing risk of extinction (Hilborn et al. 2003, Schindler et al. 2010, Moore et al. 2010, Carlson and Satterthwaite 2011). A diverse portfolio of life-history strategies is especially important in changing landscapes, where it is unknown which strategies will succeed in the face of watershed disturbances and environmental and climatic changes. Because only a fraction of the thousands of eggs laid by a female salmon, lamprey, or sturgeon will survive to return as adults, having a diversity of life-history strategies in the population increases the chances that, each year, at least some individuals will experience suitable conditions and survive to continue the next generation, increasing population stability and resilience (Hilborn et al. 2003, Schindler et al. 2010).

As introduced in Section 2.2, a mosaic of connected habitats distributed across space and time provides the potential for the expression of diverse fish life-history strategies, which both increases population resilience and results in greater overall abundance (Moore et al. 2014, Atlas et al. 2023, Cordoleani et al. 2023, Rossi et al. 2024*)*. The limited area of habitat in natal streams limits their carrying capacity. Thus, when juvenile fish can spread out across the watershed and use diverse, non-natal habitats (including habitats that are only seasonally suitable), the watershed's overall rearing habitat area and associated carrying capacity increases, thereby increasing population abundance and resilience. The critical need for diverse habitats underscores the importance of a basin-wide restoration and conservation strategy that addresses habitat impairments across a diversity of habitat types.

Despite the increasing recognition of the fundamental role life-history diversity plays in abundance, persistence, and stability of anadromous fish populations, management and restoration strategies tend to focus on widely recognized life-history strategies that are currently present on the landscape, often overlooking strategies that may have contributed significantly to the great historical abundance of Eel River fish populations but are less common now. Specifically, restoration planning and implementation efforts in the Eel River have been weighted heavily toward protection and restoration of physical habitat in cold, low-gradient tributaries that support juvenile natal stream rearing life-history strategies (those that spend a year or more in their natal streams before emigrating to the ocean) for Coho Salmon and steelhead (NMFS 2014, 2016; South Fork Eel River SHaRP Collaborative 2021). Continued focus on protecting and restoring these cold natal streams is justified because they are salmon strongholds, and under current conditions, natal life-history strategies likely contribute to a large fraction of fish populations in most years. However, even when fully restored, the juvenile habitat capacity of natal streams is likely insufficient to produce the great abundance of returning adults that historically occurred in the Eel River. It follows that other life-history strategies, such as early emigrants that rear along mainstem corridors, in the stream-estuary ecotone, or in non-natal tributaries, must have contributed substantially to the historical abundance, and likely still contribute to abundance and resilience of current population to some degree. More importantly, recovery of the Eel River's anadromous fish population may depend on recovering life histories that are currently depressed or rare, rather than increasing the capacity of life histories that are common today. For this reason, understanding, protecting, and restoring non-natal juvenile life-history strategies—as well as less commonly recognized adult life-history strategies—are fundamental to recovering native fish populations and are a core focus of the Plan. As described below, the life-history conceptual models were developed to help identify and describe the suite of life-history strategies with potential to exist in the watershed (including those that have been extirpated), determine that factors that may be limiting their expression, and outline strategies for restoring them.

3.2.3 Life-history Conceptual Model Approach

Understanding the factors that control the abundance and persistence of returning adult anadromous fish is an extremely complex undertaking, particularly for a large watershed like the Eel River. Developing a life-history conceptual model for each species provides a framework to (1) organize the available information, (2) identify data gaps and testable hypotheses, (3) identify factors potentially limiting production of each life stage and life-history strategy, and (4) inform efforts to identify and prioritize restoration strategies that are most likely to increase population size and resilience.

The Planning Team synthesized information on status, current and historical distribution, ecology, life-history timing, and habitat needs of each life stage for each focal species in the Eel River watershed (Appendix D). Building on this review and drawing on information from other watersheds in the region, the Planning Team developed diagrams to help (1) identify the potential suite of adult and juvenile life-history strategies (and variation within each) with the potential to occur in the Eel River watershed and (2) visualize how different strategies use different parts of the watershed across space and time. Figure 3-2 shows an example of a life-history diagram developed for Coho Salmon. In this example, primary juvenile life-history strategies are shown in different colors. Within each strategy, the suite of more specific life-history pathways with the potential to occur in the Eel River are shown. For instance, after leaving natal streams in the fall, individuals in the “fall parr emigrant” strategy have the potential to spend the wet season rearing in mainstems, non-natal streams, or the stream-estuary ecotone.

After creating life-history conceptual diagrams, the Planning Team developed accompanying narratives to describe primary juvenile and adult life-history strategies for each focal species. Depending on species, these narratives generally include discussion of the following:

- Overall behavior, ecological interactions, and time frames spent in natal and non-natal habitats (for juveniles);
- Potential variations (pathways) within each strategy and evidence for their current and historical distribution and prevalence in the Eel River watershed;
- Natal and non-natal stream conditions and channel archetypes (Section 2.2) that support each life-history strategy and example streams with these conditions;
- Influence of annual variation in hydrological patterns on expression and survival of each strategy;
- Primary factors affecting survival and prevalence of each strategy, including factors occurring within rearing and spawning habitats, and factors influencing survival during transitions between habitats; and
- Key data gaps and level of certainty in knowledge about life-history diversity and stressors of each species.

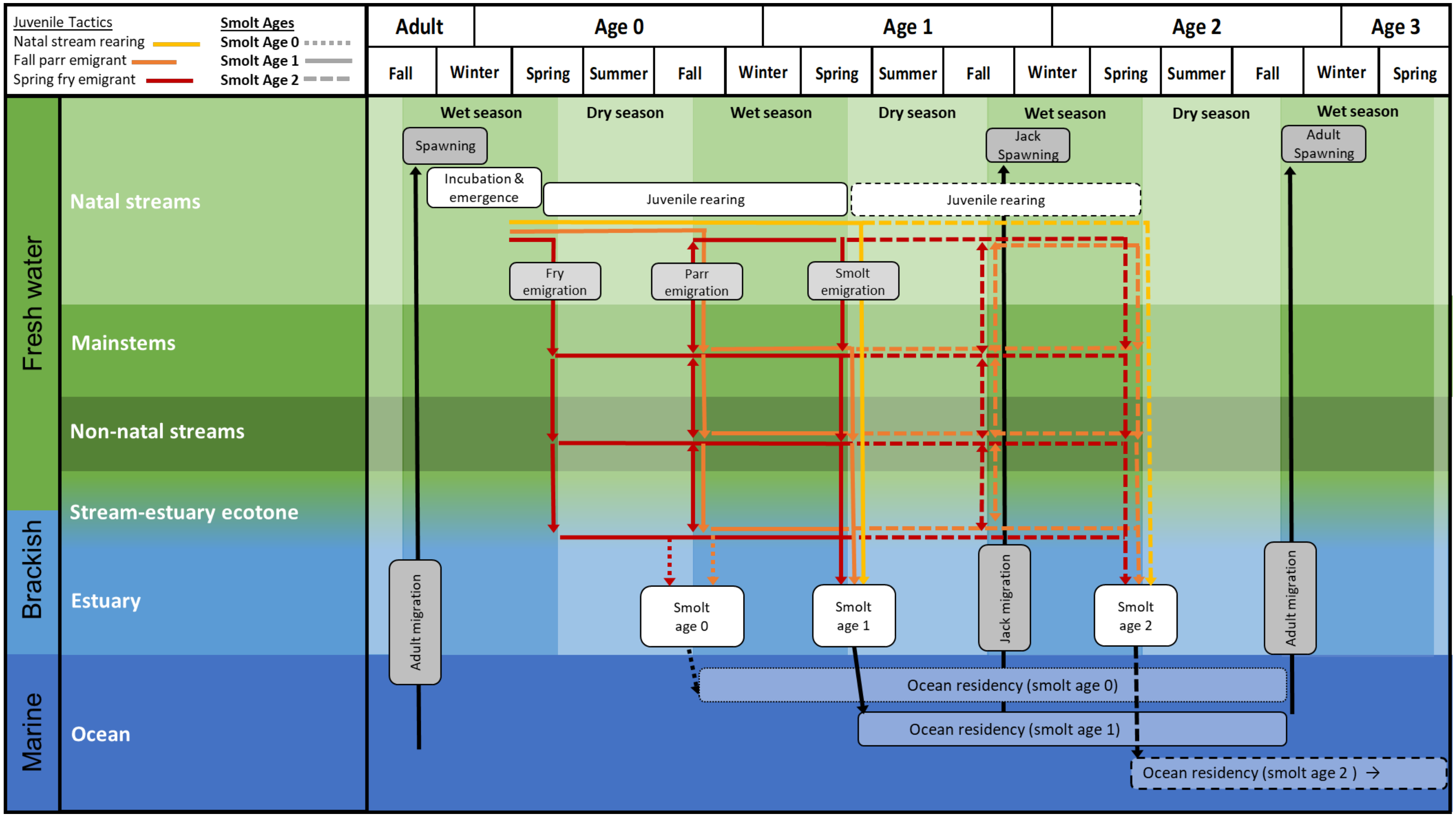


Figure 3-22. Example of a life-history conceptual diagram for Coho Salmon in the Eel River. The diagram shows potential movement pathways across time (X-axis) and space (Y-axis) for primary juvenile life-history strategies, which are represented by yellow, orange, and red lines. Each line represents a potential pathway within a strategy. The direction of the arrows represents the directions of movement between primary portions of the watershed. Refer to Appendix D for further description of these diagrams and the associated species conceptual models.

3.2.4 Key Outcomes

The information compiled and understanding gained from focal fish species descriptions and life-history conceptual models was used to:

- Identify a draft list of likely stressors for each species (Section 3.2.4.1);
- Identify and describe key themes and strategies for restoration and conservation (3.2.4.2); and
- Catalog important data gaps (Section 3.2.4.3) to help identify research and monitoring activities needed to address them.

This section provides a higher-level synthesis of these outcomes across all focal species. More detailed lists of stressors, restoration strategies, and data gaps for each species are provided in Appendix D. Importantly, as described in Section 5, the species' conceptual models will also be used in the proposed prioritization process as a tool to determine the most impactful stressors for each species and to help identify the priority restoration and conservation actions for addressing them.

3.2.4.1 Identified stressors to focal species

Table 3-3 lists the stressors with potential to contribute to loss of population productivity and resilience for one or more of the focal species in the Eel River watershed. The table also includes preliminary ratings of the level of certainty that each stressor has significant impact on each species. Herein, stressors are defined as:

> *Physical, environmental, or biotic factors driven by anthropogenic impacts that can significantly impair natural watershed or ecological processes and negatively impact habitat capacity, growth, survival, and diversity of focal species in the Eel River, contributing to less abundant and resilient populations.*

The list of stressors was generated from the species conceptual models (Appendix D), along with existing recovery plans and species assessments (e.g., NMFS 2014, 2016; Stillwater Sciences 2014; Stillwater Sciences and Wiyot Tribe Natural Resources Department 2017). While each stressor listed in Table 3-3 has the potential to adversely affect one or more life stages of each of the focal species, some stressors are expected to be more important than others in terms of limiting population productivity or expression of life-history diversity for certain species. Appendix D includes more in-depth discussion about the factors hypothesized to have the greatest influence on abundance and resilience of each species. As described in Section 5, this information will be an important input into the process for prioritizing restoration and conservation objectives during Phase 2 of the Program. Section 4 provides a suite of restoration and conservation actions that address likely stressors to focal fish species. This action list—which was also informed by existing recovery plans, species assessments, and a hierarchical process to identify tiered goals and objectives—will serve as the starting point for selecting actions that most directly address priority restoration objectives identified in Phase 2 of the Program (Section 5.2.2).

Table 3-3. Stressors identified through species conceptual models and existing species assessments with potential to contribute to less abundant and resilient populations of focal species in the Eel River watershed.[1]

Stressor category	Stressor	Chinook Salmon	Coho Salmon	Steelhead	Pacific Lamprey	Green Sturgeon
Fish passage barriers	Anthropogenic physical barriers to movement	X	X	X	X	?
	Flow or sediment related barriers to seasonal movement	X	X	X	x	?
	Reduced connectivity with estuarine habitats	X	X	X	x	X
Physical aquatic habitat	Reduced area of low-velocity winter refuge habitats		X	X	x	?
	Impaired connectivity with and loss of floodplain rearing habitats	X	X	X	X	?
	Alteration of estuarine habitat quantity and quality	X	X	X	X	X
	Loss of escape cover from predators	X	X	X	X	X
	Reduced pool frequency and depth in mainstems and tributaries, loss of thermally stratified pools	X	X	X	x	X
	Channel bed and redd scour	x	x	x	x	?
	Fine sediment infiltration of spawning substrates and redds	X	X	X	X	X
Instream flows	Impaired dry-season stream flows	X	X	X	X	X
	Impaired fall pulse flows	x	?	x	?	?
	Impaired spring recession flows	X	x	X	x	x
Water quality	High water temperatures	X	X	X	X	X
	Reduced area of and access to coldwater habitats	X	X	X	x	x
	Low dissolved oxygen concentrations	?	?	?	?	?
	Exposure to toxins from urban and agricultural run-off	?	?	?	?	?
	Elevated turbidity levels beyond reference state levels	?	x	x	?	?
Population structure	Lost genetic diversity	X	X	X	?	X
	Altered adult age and spatial structure	X	x	x	?	?
	Lost life-history diversity	X	X	X	x	x
Species interactions and food resources	Lost beneficial species interactions	x	x	x	x	x
	Increased prevalence of disease	?	?	?	?	?
	Introduced predators such as Sacramento Pikeminnow and anthropogenic factors that increase vulnerability to them	X	X	X	X	x
	Introduced competitors and anthropogenic factors that increase vulnerability to them	X	X	X	?	x
	Loss of marine-derived subsidies and nutrients	X	X	X	X	X
	Alterations to the timing, magnitude, and availability of food resources	X	X	X	x	x
Harvest	Ocean harvest or bycatch	X	x	x	?	?
	Poaching	x	x	x	?	x

[1] X = known stressor; x = likely stressor; ? = unknown stressor

3.2.4.2 Important themes informing restoration and conservation priorities

During the development of life-history conceptual models and identification of key stressors—and during various internal and TAC discussions—the Planning Team identified the following central themes and focus points related to recovery of focal fish species in the Eel River watershed.

Coldwater habitats

Identifying, protecting, restoring, and improving access to coldwater habitats across the watershed is essential for protecting and restoring focal species in the face of climate change. At the watershed-scale, these habitats include important coldwater tributaries, headwater streams, and estuarine habitats that can support focal species through the summer during drought years. Restoring anadromous fish access to and improving habitat within the coldwater habitats upstream of Scott Dam is a high priority. At smaller, within-reach scales, these habitats include thermal refugia within thermally-stratified pools, coldwater plumes associated with tributaries and springs, coldwater reaches associated with upstream hyporheic or sub-surface flows, and other anomalously cold habitats in otherwise warm reaches. Restoration planning efforts should emphasize restoring habitat at tributary confluences and improving connectivity between mainstems and the lower reaches of tributaries, which provide refugia from both high temperatures in the summer and, as described below, high stream flows in the winter.

Habitat heterogeneity and non-natal rearing habitats

Extensive, annually variable and, sometimes, large-scale movements of focal species between diverse types of habitats suggest a system-wide approach to habitat restoration is needed to maximize production and resilience of focal fish species. Continued efforts in the protection and restoration of salmonid stronghold streams—low-gradient, coldwater tributaries that support year-round juvenile rearing by natal life-history strategies—are crucial to the persistence and recovery of focal fish populations. However, as discussed previously, even complete restoration of natal streams will be insufficient to return focal fish populations to historical abundance. The life-history conceptual models illuminate the pressing need to expand efforts to protect and restore a mosaic of non-natal rearing habitats that provide variable conditions within and between years for early emigrant strategies (i.e., individuals that leave the natal streams in the spring as fry or in the fall as parr).

Specifically, restoring a mosaic of non-natal habitat features between natal streams and the ocean, which can be used across variable conditions within and between years, is a critical component to fostering juvenile fish life-history diversity. Non-natal habitats with potential to provide seasonally productive rearing conditions and increased carrying capacity for focal species include (1) mainstem habitats; (2) off-channel ponds, beaver ponds, and wetlands along mainstem corridors (Petersen 1982, Soto et al. 2016); (3) perennial tributaries (Skeesick 1970, Stillwater Sciences 2023); (4) small, intermittent tributaries (Ebersole et al. 2006, Wigington et al. 2006); (5) large unconfined valleys, such as Little Lake Valley, that historically provided extensive winter rearing habitat (NMFS 2014); and (6) estuarine habitats such as tidal wetlands and sloughs (Miller and Sadro 2003, Koski 2009, Jones et al. 2014, Rebenack et al. 2015, Wallace et al. 2015).

Both natal and non-natal streams that are too warm to support salmonids through the summer have largely been overlooked in efforts to restore fish populations in the Eel River, but these streams have potential to provide high-quality rearing habitats during the wet season that can substantially contribute to overall population abundance and resilience. Even small streams that become intermittent in the summer can provide excellent non-natal rearing and winter refuge habitat during the wet season (Skeesick 1970, Ebersole et al. 2006, Wiginton et al. 2006). For example, Ebersole et al. (2006) found high Coho Salmon overwinter survival and growth rates in a small tributary relative to adjacent mainstem reaches. In addition to providing winter rearing habitats, drier or intermittent streams (associated with Central Belt mélange) can provide better conditions for rapid fry and juvenile growth during the spring relative to cold perennial streams (associated with Coastal Belt turbidites) because of their quicker rate of flow recession and warmer water temperatures during that season, which are driven by differences in underlying geology (Figure 3-3, Dralle et al. 2023). Finally, stream reaches that are not habitable during warmer, drier portions of the year can still drive food production, fish growth and life-history diversity during cooler, wetter portions of the year (Armstrong et al. 2021).

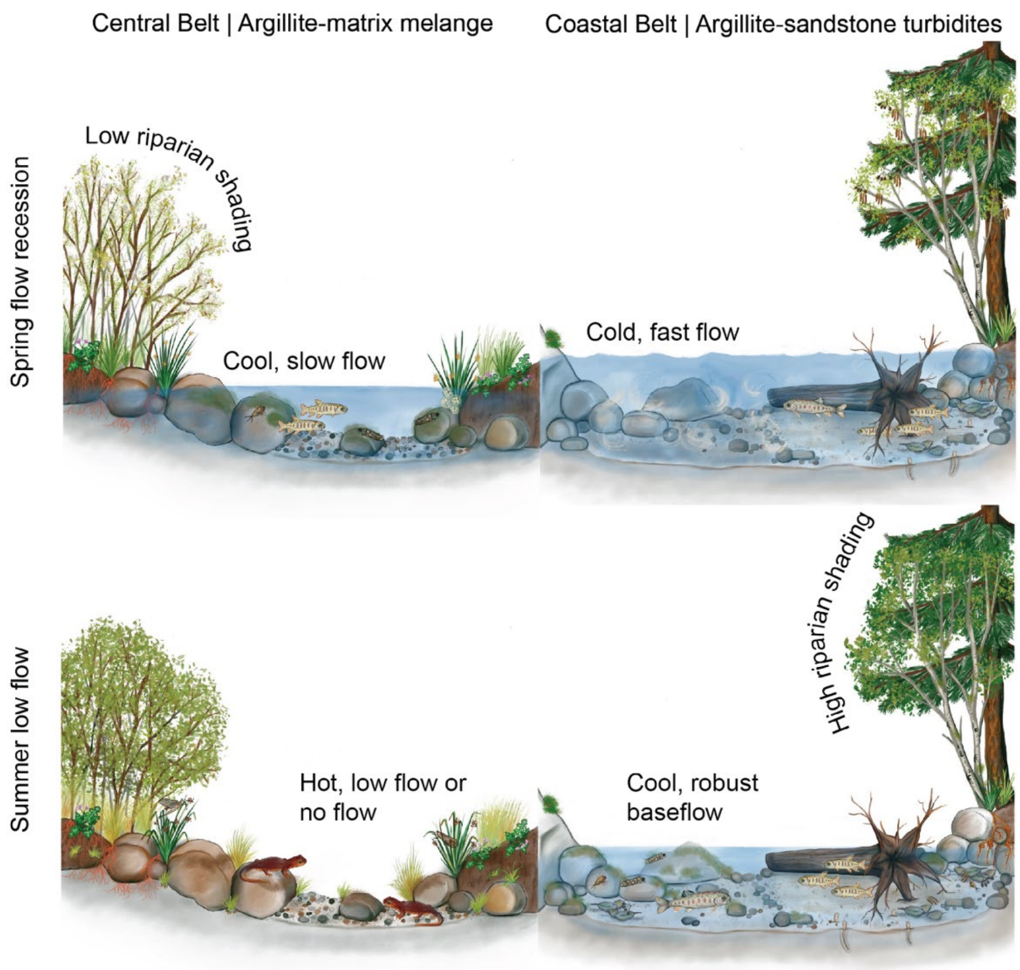


Figure 3-33. Typical progression of stream conditions between the Central Belt mélange (left) and Coastal Belt turbidities (right) following the last significant rainfall event of the wet season. The top row illustrates conditions in the spring/early summer when air temperatures have begun to increase, and streamflow is beginning its long seasonal recession. The bottom row depicts late summer low-flow conditions when air temperatures are high and water availability in the stream is approaching its annual minimum. (Figure and caption used from Dralle et al. (2023) with permission).

In addition, restoring the high-value non-natal habitat described above, another important strategy for restoring life-history diversity is to identify and restore other unique habitats across a range of scales in the watershed. One important example of such unique habitats are the large valleys that are present in more inland portions of the watershed. These valleys include Little Lake Valley (Outlook Creek drainage in the Upper Main Eel sub-watershed), Round Valley (Mill Creek drainage in the Middle Fork Eel sub-watershed), upper Tenmile Creek (near Laytonville in the South Fork Eel sub-watershed), and Gravelly Valley (mostly under Lake Pilsbury in the Upper Main Eel sub-watershed, Figure 3-4). Prior to widespread habitat degradation and hydrological alteration associated with European settlement, agricultural and urban development, and resource extraction; the low-gradient, unconfined channels found in these valleys likely provided extensive, complex, and high-quality spawning and rearing habitats that contributed to the diversity and resilience of focal species populations.

Figure 3-4. Gravelly Valley and the upper mainstem Eel River in the winter of 1910, looking north toward the Salmon Creek and Smokehouse Creek drainages and Hull Mountain. Note the complex network of streams and side channels running through the large valley (Source: California Historical Society Collection 1860–1960).

Other examples of unique habitats that warrant additional restoration and conservation planning attention include (1) locally unconfined mainstem channel segments with high potential for floodplain connectivity in otherwise confined reaches and (2) very low-gradient channels that are highly connected to floodplain areas across a range of stream flows. The latter habitat, sometimes referred to as "swampy meadow units," often occur in upper basin areas where channels are underfit to the relatively large valleys where they occur, typically due to a reduction in former drainage area caused by stream capture. These channels, which share many of the characteristics of "stage zero" channels described by Cluer and Thorne (2013), are often braided and contain deep sediment deposits, accumulated organic material, and wetland vegetation such as sedges (Figure 3-5). In addition to likely providing high-quality summer rearing habitat for salmonids, these headwater reaches provide excellent winter refuge habitat due to their relatively low flows and seamless connectivity with the floodplain that attenuates flood peaks. These unique channel types also provide different stream insect assemblages than adjacent reaches with rocky substrates (M. Power, UC Berkeley, pers. comm. 2024). Examples of this habitat type can be found in various tributaries along the western edge of the South Fork Eel River watershed, such as Redwood Creek (tributary to upper South Fork Eel River), upper Anderson Creek (tributary to Indian Creek), and tributaries to Hollow Tree Creek (Figure 3-5)

Figure 3-55. Example of an anomalous low-gradient headwater habitat in a tributary to Hollow Tree Creek in the South Fork Eel River sub-watershed.

Stream-estuary ecotone and estuary

Historically, the stream-estuary ecotone and estuary likely provided the most productive and vast non-natal rearing habitats in the Eel River watershed. Widespread degradation and disconnection of lower mainstem and estuarine winter habitats due to diking, tide gates, and agricultural conversion have diminished their habitat capacity and quality, and along with them, life-history diversity. For this reason, conserving and restoring these habitats is fundamental to meeting restoration goals.

An ecotone is an area of transition between two biological communities that is often richer in species and biomass than the surrounding communities (Koski 2009). The stream-estuary ecotone, which encompasses the lower reaches of coastal watersheds where streams transition into estuaries, is particularly valuable for habitat restoration and recovery of anadromous fish (Jones et al. 2014, Wallace et al. 2015, Flitcroft et al. 2016). In addition to providing unique and highly productive habitats that promote life-history diversity, the stream-estuary ecotone and estuary can play an outsized role in influencing growth, survival, and population dynamics of anadromous species because entire populations must pass through them, first as juveniles and then as adults (Bottom et al. 2005, Bond et al. 2008, Hayes et al. 2008, Koski 2009, Bennett et al. 2014, Jones et al. 2014, Wallace et al. 2015).

Numerous studies have shown that favorable growth conditions in estuaries can enable juvenile salmonids to recruit disproportionately to the adult population compared with fish that rear in upstream habitats because larger individuals typically have higher ocean survival rates (Miller and Sadro 2003, Bond et al. 2008, Koski 2009, Jones et al. 2014). Moreover, restoration of estuaries has been shown to increase salmonid life-history diversity. For example, extensive restoration of estuarine tidal wetlands in the Salmon River in Oregon increased variation in both Chinook Salmon and Coho Salmon juvenile rearing strategies, enhancing the species' overall life-history diversity and resilience in the watershed (Bottom et al. 2005, Flitcroft et al. 2016).The estuary and lower mainstem Eel River are also essential habitats for adult salmonids, Pacific Lamprey, and Green Sturgeon, which often stage there at the onset of during their spawning runs. Additionally, estuaries are known to be feeding habitats for both juvenile and adult Green Sturgeon (Allen et al. 2009, Nakamoto et al. 1995, Lindley et al. 2011).

Seasonal habitat capacity of natal streams may become limited during extreme climatic events such as droughts and floods. During these periods, the relative importance of the estuary, lower mainstem Eel River corridor, and adjacent tributaries increases. During extreme drought years when many tributaries become too dry or hot to support summer rearing or their habitat capacity decreases, the importance of the lower mainstem Eel River and estuarine habitats for the population is expected to increase. Likewise, during wet winters with high-magnitude flood events, greater downstream displacement of juvenile fish places greater importance on winter rearing habitats in the lower Eel River watershed and stream-estuary ecotone. Given the recent predictions of increased frequency of extreme climatic events in the region (Swain et al. 2018), these dynamics highlight the importance of the recent and ongoing habitat restoration (e.g., Salt River, Cannibal Island, Cock Robin Island, and Ocean Ranch), conservation (e.g., Eel River Estuary Preserve), and planning (e.g., lower Eel River SHaRP) efforts being conducted in lower portions of the watershed and estuary.

Lower watershed mainstem corridors

Restoring and protecting the lower reaches of the mainstem Eel, South Fork Eel, and Van Duzen rivers—along with adjacent off-channel habitats and the lower reaches of their tributaries—are also critically important for the recovery of focal species. As with the estuary, a large portion of the watershed's anadromous fish populations must pass through or rear in these reaches. In addition to providing habitat for migrating adults and out-migrating juveniles, these reaches have potential to provide large areas of excellent non-natal rearing habitat. Along mainstem river corridors, low-velocity winter rearing habitats may occur in floodplain channels with ponded features or off-channel ponds connected to the mainstem by small channels (Soto et al. 2016). Such features are often associated with small tributaries, which can (1) help maintain connectivity with the mainstem; (2) improve water quality in off-channel habitats during drier winter periods; and (3) provide clearwater feeding habitats during high flows when high turbidity levels in adjacent mainstems can cause negative physiological effects, impair feeding, and prompt juvenile salmon to seek refuge habitats (Bisson and Bilby 1982, Sedell et al. 1990, Soto et al. 2016). Low-gradient tributaries entering the lower mainstems of the Eel, South Fork Eel, Van Duzen rivers (e.g., Price, Strongs, and Barber creeks) are expected to have particularly high potential to provide valuable non-natal rearing habitats for early emigrant life-history strategies during both the dry and wet seasons. For this reason, assessing and restoring habitat in and connectivity to these streams is important for increasing the prevalence of early emigrant strategies.

Highway and levee construction and sediment deposition from logging and large floods have altered much of the lower mainstems of the Eel, South Fork, and Van Duzen rivers, as well as the lower reaches of their tributaries, resulting in degraded or disconnected off-channel features within the watershed. Such changes are expected to have lowered the survival and prevalence of the early juvenile emigrants. Filling of deep pools in the mainstem and loss of mainstem habitat complexity, including a reduced supply of large wood, have also likely resulted in decreased survival of early emigrants during their movements from natal to non-natal habitats and during smolt emigration. These habitat alterations, along with the introduction of non-native Sacramento Pikeminnow, have further diminished the prevalence of these life histories. By reducing the quantity and quality of adult holding habitats and limiting connectivity between them, channel aggradation and other habitat alterations in the lower mainstem Eel River also negatively influence early-migrating adult salmonids during their spawning runs, particularly Chinook Salmon and in years with lower streams flows during the fall.

Beaver-assisted habitat restoration

The North American Beaver (*Castor canadensis*) is a keystone species and ecosystem engineer that supports numerous other species by altering stream geomorphology and hydrology and creating and maintaining high-quality and diverse aquatic and riparian habitats (Naiman et al. 1988; Pollock et al. 2003, 2004, 2007, 2014; Dewey et al. 2022). Beaver dams and associated ponds, bank lodges, side channels, and burrows can create large areas of prime summer and winter rearing habitat for juvenile salmonids and other fish (Swales et al. 1986, Pollock et al. 2004, Parish 2016). For example, during the winter, juvenile Coho Salmon rearing within side channels created by beaver dams occur at higher densities and have higher growth and survival rates than individuals rearing within side channels without beaver dams (Bustard and Narver 1975, Swales et al. 1986). Beaver dams can also reduce water velocities during high-flow events, providing winter refuge habitat for Coho Salmon and other species (Pollock et al. 2003, Lundquist and Dolman 2020). By slowing and spreading out stream flows, beaver dams also create wetlands and promote groundwater recharge that can enhance summer base flows and fish habitats in downstream reaches (Lundquist and Dolman 2020, Dewey et al. 2022).

Although beaver appear to be reestablishing in parts of their historical range (Lundquist et al. 2013), their abundance and distribution in the Eel River watershed and California are greatly depressed from historical levels, largely due to intensive trapping and habitat modification (Lundquist et al. 2013, Lundquist and Dolman 2020). Because of the ecological benefits described above and the diminished presence of beaver on the landscape beaver-assisted restoration through reintroduction of the species into suitable areas and the restoration of habitat and ecological processes through simulated beaver dams (beaver dam analogs) have potential to be core actions for recovering focal fish species in the Eel River watershed, warranting additional attention under the Program. Beaver-assisted habitat restoration is expected to be more cost effective than many active restoration methods because beavers (rather than heavy machinery) create the habitat and, importantly, sustain it. Beaver reintroduction may be particularly well suited for the remote and inaccessible (yet still degraded) portions of the watershed where active restoration can be logistically infeasible or cost prohibitive. Initially, focused assessments of present-day distribution and the potential for beaver reintroduction in the watershed are needed.

In addition to directly addressing the Program goals of (1) restoring abundance and resilience of native fish populations and (2) incorporating ecological processes into restoration, beaver-assisted restoration is expected to be an effective, low-cost strategy for increasing resilience to climate change–induced drought and wildfire in the Eel River watershed (Lundquist and Dolman 2020, Fairfax and Whittle 2020, Dewey et al. 2022). Moreover, focused efforts to evaluate and implement beaver-assisted restoration opportunities in the Eel River watershed are aligned with CDFW's recently established Beaver Restoration Program, which aims to "...implement beaver-assisted restoration projects to support ecosystem conservation, habitat restoration, species conservation, and improve climate change, drought, and wildfire resilience throughout California."

Foodscapes

The importance of physical habitat heterogeneity and non-natal habitat use is described above; however, the success of juvenile anadromous fish in these dynamic environments depends on their ability to grow, which is also a function of biotic conditions, including the abundance, quality, and accessibility of prey (Rossi et al. 2024. The dynamic changes in food abundance, food accessibility, and consumer energetics that contribute to spatial and temporal variation of fish growth in rivers is termed *foodscapes* (Rossi et al. 2024. Historically, food sources for anadromous fishes in the Eel River watershed included a combination of instream prey resources, terrestrial invertebrates, and marine-derived nutrients from tissue and eggs delivered by anadromous fish. In a healthy watershed, fluxes of these resources vary through time and may occur as pulses that, while short in duration, can be dominant sources of annual energy intake for any population of focal species. Such food resources can control the abundance of fish populations as much as habitat quality. However, impairments to the Eel River watershed such as levees that cut off floodplains, channel aggradation from floods and logging activities, the introduction of invasive pikeminnow, and the decline of marine-derived subsidies affect the production of food and the ability of native fish to track and exploit food resources. For these reasons, foodscapes in the Eel River warrant further consideration in restoration planning and design of restoration actions. Rossi et al. (2024) define the central question of foodscape restoration as: How have patterns and processes affecting food abundance, food accessibility, and physiological growth potential been degraded and how can they be recovered? More focused questions follow from this question and include: Have important trophic pathways, which could help re-establish critical consumer populations and life histories if restored, been impaired? How might consumers track resources across the landscape (or riverscape) if the foodscape was healthy? These questions should be applied to help prioritize and guide restoration actions in the Eel River.

Survival of juvenile emigrants

Survival of fry and parr (or larval lamprey) as they move between natal streams and non-natal habitats smolt (or juvenile lamprey) during outmigration to the ocean is likely a key factor driving abundance of returning adults, warranting more research and attention. For example, during a 5-year study in the Sacramento River, Michel (2019) found that survival during Chinook Salmon outmigration to the ocean ranged from 3–17%, while marine survival ranged from 4–23%. A related analysis of 20 years of survival data by the author suggests that smolt-to-adult survival was primarily driven by survival during outmigration to the ocean, except in years of low marine productivity. Preliminary results from an ongoing acoustic telemetry study evaluating survival of Coho Salmon smolt emigrating from natal streams through the mainstem South Fork Eel River during the spring found an average survival (across tag groups from different streams) was about 20% in one year of study (G. Rossi, U.C. Berkeley pers. comm., 2024). Because of the importance of survival during this life stage, further research is needed to (1) describe inter- and intra-annual differences in survival of out-migrating salmonids, lamprey, and sturgeon in the Eel River and (2) identify and address the mechanisms of mortality.

Sacramento Pikeminnow

One likely important source of mortality for both out-migrating smolt and rearing juveniles is predation by non-native Sacramento Pikeminnow, a large piscivorous cyprinid that was introduced into Lake Pillsbury in the upper mainstem Eel River around 1979 and has since expanded its distribution across the watershed (Brown and Moyle 1997, Kinziger et al. 2014). Pikeminnow occur at very high densities in many parts of the watershed (e.g., White and Harvey 2001, Higgins 2020, PG&E 2020, Georgakakos 2020) and therefore have potential to fundamentally alter the aquatic ecosystem and negatively impact native species—particularly, anadromous species, which must migrate from headwater streams through the mainstem to reach the estuary and ocean. Numerous studies indicate that pikeminnow compete with, prey on, or alter the behavior of juvenile salmonids, lampreys, and other native fishes in the watershed (e.g., Brown and Moyle 1997, White and Harvey 2001, Reese and Harvey 2002, Nakamoto and Harvey 2003, Georgakakos 2020). The presence of pikeminnow has likely selected against important life-history strategies that may have been historically abundant, such as mainstem rearing in the spring and summer by juvenile salmonids. The presence of pikeminnow may also favor earlier emigrating individuals that move rapidly through the mainstem corridor to the ocean, potentially selecting against individuals that spend more time feeding and growing in the mainstem and stream-estuary ecotone through the spring and early summer.

3.2.4.3 Key data gaps

The species descriptions and conceptual models developed herein are meant to capture the current state of knowledge of focal species and to be used as a reference for making informed decisions about restoration and conservation priorities (Section 5). Importantly, the conceptual models are also intended to (1) systematically identify and highlight uncertainties and gaps in the understanding of these species and the factors limiting their abundance and (2) help generate hypotheses that can be tested through targeted research (Section 7.3.3.1). For this reason, these models should be viewed as iterative and periodically refined as the state of knowledge improves in response to research and monitoring designed to fill these gaps (Section 7). Table 3-4 lists the key data gaps identified for one or more of the focal species. Notably, the extent to which each item is a data gap varies by species and location. In general, data gaps with potential to constrain effective species management or limit informed prioritization and implementation of restoration and conservation actions are listed. Appendix D provides a more comprehensive list and discussion of key data gaps and associated research and monitoring needs for each species. As described in Section 5.2.2.2, additional key data gaps will be identified during the prioritization process proposed for Phase 2.

Table 3-4. Key data gaps that may impair effective species management or limit informed prioritization and implementation of restoration and conservation actions. [1]

Life stage	Focal species data gap	Chinook	Coho	Steelhead	Pacific Lamprey	Green Sturgeon
Adult holding and migration	Adult population size and trends by sub-watershed	x	x	X	X	X
	Distribution of holding adults and preferred adult holding habitats.	x	x	x	X	X
	Prevalence, distribution, and genetic relatedness of distinct adult run ecotypes			x	X	
	Historical prevalence and distribution of adult life-history strategies	X	x	X	X	X
	Adult survival in fresh water (pre-spawning mortality) and factors affecting it	x	X	X	X	X
	Locations and extent of anthropogenic barriers to migration	x	x	X	X	X
Spawning and incubation	Spawning distribution	x		x	X	X
	Survival from spawning until fry/larval emergence	X	X	X	X	X
	Quantity and quality of suitable spawning habitat. Changes in spawning habitat conditions and recovery trajectory from alteration of sediment dynamics by floods, logging, and other anthropogenic disturbances.	X	X	X	X	X
Juvenile or larval rearing and movement	Seasonal distribution (not just in the summer)	X	X	X	X	X
	Current prevalence and distribution of early emigrant life-history strategies in non-natal rearing habitats within and between years with variable environmental conditions—including in mainstems, adjacent off-channel habitats, warm and cool non-natal tributaries, and the estuary.	X	X	X	X	
	Historical prevalence and distribution of juvenile life-history strategies	X	X	X	X	X
	Timing of movements between natal streams and non-natal rearing habitats and survival during these movements.	X	X	X	X	X
	Fry-to-smolt survival (or larval to juvenile survival for lamprey and sturgeon). Spatial and temporal variation in juvenile survival.	X	X	X	X	X
	Locations, habitat characteristics, and use of thermal refugia within mainstems and larger tributaries.	X	X	X	X	X
	Spatial, seasonal, and interannual variation in in-situ food resources, across rearing habitats.	X	x	x	X	X
	Existence of, and spatial, seasonal, and interannual variation in, food subsidies (e.g., from fish eggs or terrestrial invertebrates) that provide growth opportunities. How subsidies have been altered and how they can be restored.	X	X	X	X	X
	Spatial, seasonal, and interannual variation in physiological growth potential (bioenergetics) and prey accessibility. Influence of restoration on these factors.	X	X	X	X	X
Juvenile emigration to ocean	Salmonid smolt or juvenile lamprey and sturgeon production from important spawning streams.	X	X	X	X	X
	Survival of emigrating smolt or juveniles between natal streams and the ocean across time and space. Where are the mortality hotspots and why?	X	X	X	X	X

Life stage	Focal species data gap	Chinook	Coho	Steelhead	Pacific Lamprey	Green Sturgeon
Ocean residence	Ocean survival and influences of ocean conditions, prey composition and abundance, harvest management practices, and bycatch from other fisheries.	X	X	X	X	X
	Prevalence of Thiamine Deficiency Complex due to changes in ocean diet and associated mortality of offspring during the embryo and fry stages	X	X	X		
Other	Impacts of pikeminnow predation, presence, and competition on native focal species and how these impacts vary spatially and temporally	X	X	X	X	X
	Influence of other non-native aquatic predators and competitors such as Largemouth Bass and Brown Bullhead	X	X	X	X	X
	Water temperatures from fall through spring (not just summer)	X	X	X	X	X
	Prevalence and distribution of fish diseases and factors influencing them	X	X	X	X	X

[1] X = significant data gap; x = moderate data gap

4 RESTORATION AND CONSERVATION ACTIONS

Section 1.2.2 defines the terms *restoration* and *conservation* for this Plan. This section describes the process for and outcomes of identifying a suite of actions that will help achieve the Program restoration and conservation goals (Section 1.2.1) and address the stressors to focal fish species (Section 3.2.4.1). Section 4.1 describes the approach for identifying and organizing actions, then Section 4.2 summarizes the tiered goals and objectives that were used to help identify actions, and finally Section 4.3 lists and describes identified action categories. Appendix E provides more detailed tables of tiered goals and objectives, and Appendix F provides more detail on restoration and conservation actions. The restoration and conservations actions identified herein are not an exhaustive list, but rather an initial working compilation of actions that will help achieve Program goals and alleviate one or more of the stressors identified for focal species (Section 3). Ultimately, restoration and conservation actions identified here will be used as inputs to the Phase 2 prioritization process, which will be designed to identify priority actions expected to be most effective at achieving Program goals and that will most directly address stressors that are limiting fish population recovery.

4.1 Approach for Identifying and Organizing Actions

Restoration and conservation actions were identified based on tiered goals and objectives, along with inputs from the species conceptual models (Section 3.2) and existing assessments and plans that identify key restoration and conservation actions (e.g., recovery plans, SHaRP) (Figure 4-1).

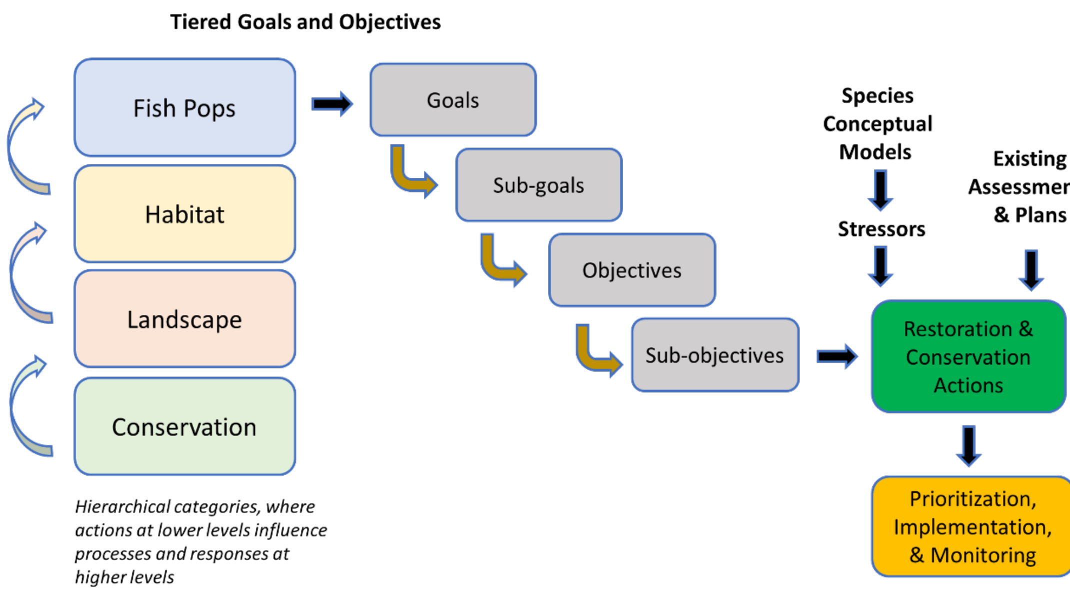


Figure 4-1. Process for identifying restoration and conservation actions.

The tiered goals and objectives approach initially involved identifying broad goals for the following hierarchical categories of watershed influence: *Conservation, Landscape, Habitat, Fish Populations*. These broad goals are consistent and encompass important elements of the Program goals listed in Section 1.2.1, including *Restore*, *Protect*, *Incorporate Ecological and Geomorphic Processes*, and *Recommend Actions*.

For the broad goals developed for each hierarchical category, the Planning Team developed increasingly specific sub-goals, objectives, and sub-objectives for restoration and conservation. Sub-objectives were identified at a resolution that is more appropriate for linking with specific restoration and conservation actions. The outcome of this process is shown in a series of tiered goals and objectives tables that are presented in Appendix E. This tiered goals and objectives approach is similar in concept to the tiered objectives approach developed for the Trinity River Integrated Assessment Plan (TRRP and ESSA 2009).

An example of the tiered goals and objectives identified for the Fish Populations category follows:

- **Goal:** Achieve naturally self-sustaining and harvestable native anadromous fish populations
  - **Sub-goal**: Increase freshwater productivity of anadromous species (e.g., population growth rate, smolts per adult, adults per adult)
    - **Objective**: Fry-to-smolt survival—Increase survival rates through juvenile life stages by inducing favorable changes to stream habitat and competition
      - **Sub-objective**: Reduce mortality due to predation.

After developing the tiered goals and objectives tables, specific restoration and conservation actions were identified, categorized, and included in action tables (Appendix E). Actions were identified in three ways: (1) through the tiered goals and objectives process described above, (2) by identifying those expected to address stressors to focal fish species, and (3) from reviewing actions listed in existing Eel River plans (e.g., SHaRP, species recovery plans). As described in Section 3, species conceptual models were used to identify stressors with potential to limit population productivity and resilience of focal fish species. Actions thought to address the root causes, or drivers, of those stressors were then identified and added to the action tables. Similarly, existing assessments and plans have identified key stressors and/or actions needed to support species recovery objectives. The outcome of this process is a series of action tables organized by the hierarchical categories (*Fish Populations, Habitat, Landscape*, and *Conservation*) (Appendix E, Tables E-1 through E-4).

Where appropriate, actions were linked to the channel archetypes where they are most appropriate to be applied. For example, large wood additions to improve habitat complexity are generally most effective in channels with bankfull widths of about 2 to 12 meters and channel slopes from about 0.5% to 4%. These attributes correspond to a subset of channels in the low gradient and mid-gradient tributary (cold, cool, and warm) channel archetypes. Additional spatial analyses will be conducted as part of Phase 2 prioritization process to help determine where within the watershed high priority restoration and conservation actions are most appropriate and expected to have the greatest benefit to focal species (Section 5.2).

4.2 Tiered Goals and Objectives Summary

As described above (Section 4.1, Figure 4-1), the tiered restoration and conservation goals and objectives approach uses a hierarchical structure intended to provide flexibility to expand as the Program evolves and prioritization of restoration and conservation actions progresses. Table 4-1 lists the broad goals and more specific sub-goals for each hierarchical category of influence. Appendix E includes more specific objectives for each sub-goal, and more specific sub-objectives for each objective. As one gets into more specific objectives and sub-objectives, the ability to quantify, monitor, and assess those objectives increases.

4.3 Restoration and Conservation Actions Summary

Categories of restoration and conservation actions that have been identified by this Plan are summarized in Table 4-2, and more detailed actions are presented in the Appendix F action tables. The action tables (Appendix F) are intended to be a working document that will be refined and expanded with Program formation and project prioritization in Phase 2.

Within the prioritization process, restoration and conservation actions will be identified as either *broad* or *specific* (Section 5.2). *Broad actions* are general types of projects that could be applied in multiple locations such as large wood additions to promote habitat complexity. *Specific actions* are projects associated with a specific location such as a culvert that is a complete barrier to upstream fish passage at a specific road-stream crossing. The majority of restoration and conservation actions identified in the action tables (Appendix F) are *broad actions* that will require additional investigation to determine where (e.g., sub-basin, channel archetype) implementation of the action would be most beneficial, as well as considering the relative benefit of the action during the prioritization process, and ultimately whether it is identified as a high priority action for implementation.

Table 4-1. Tiered Goals for habitat and ecological restoration.

Category	Goals	Sub-goals
Fish Populations	Achieve naturally self-sustaining and harvestable native anadromous fish populations	Increase species population sizes
		Increase freshwater productivity of anadromous species (e.g., population growth rate, smolts per adult, adults per adult)
		Restore species distributions to historical extents
		Maintain and increase diversity of life-history strategies
Habitats	Improve quantity, complexity, and diversity of habitats within the stream corridor	Increase quantity of suitable habitat for focal species and life stages
		Increase complexity and quality of key habitats
		Restore connectivity between habitats
		Foster productive riverine food webs that support growth of native fishes
		Increase and improve estuarine habitat
Landscapes	Protect, enhance, and restore intrinsic physical watershed processes (e.g., hydrologic, geomorphic, and riparian) that create and maintain complex channel morphology and regulate habitat connectivity.	Protect, enhance, and restore functional flow components
		Protect, enhance, and restore geomorphic processes to healthy ranges
		Promote riparian corridor processes that support and sustain complex aquatic habitats
		Improve water quantity and quality
Conservation	Protect the Eel River's natural resources through land conservation actions that promote habitat connectivity and resiliency	Increase amount of conserved and protected land
		Establish and maintain connectivity and heterogeneity of conserved areas
		Use climate refugia strategy for planning conservation areas
		Protect ecosystem services
		Priority habitat data integration
		Protect species diversity and persistence
		Develop regional partnerships

The conservation actions were developed using a strategic planning approach to first identify conservation needs in the entire Eel River watershed. The conservation actions do not specifically crosswalk to fish habitat stressors and channel archetypes for instream habitat. Instead, conservation actions are focused on the landscape surrounding the Eel River (i.e., the riparian corridor). The initial strategic planning was focused in each of the seven primary sub-watersheds, and in specific focal areas identified as important for aquatic species, such as riparian corridors, estuaries, and mainstem rivers. Core upland habitat adjacent to riparian corridors and existing protected areas was also considered. Potential representativeness, effectiveness, and connectivity of existing protected areas were used as indicators to view where there may be gaps in habitat protection across the watershed and at different scales.

In addition to the action categories presented in Table 4-2, monitoring infrastructure will be critical for informing and understanding conditions and evaluating project-level and program-level performance (Section 7).

Table 4-2. Restoration and conservation action categories and descriptions.

Restoration and Conservation Action Categories	Description
Fish passage improvement	Actions that improve aquatic habitat connectivity by improving volitional upstream and/or downstream movement of fish and aquatic species, particularly at man-made or otherwise anthropogenic barriers and obstacles such as road-stream crossings.
Instream habitat restoration (physical habitat)	Actions that increase or improve physical habitat conditions within the active stream channel and adjacent floodplain to support greater abundance and/or life-history diversity for focal fish species.
Off-channel habitat restoration and habitat connectivity	Actions that increase or improve physical habitat conditions outside the active stream channel but within the riparian/floodplain corridor that have at least seasonal connectivity (e.g., during high flow periods) to support greater abundance and/or life-history diversity.
Estuary habitat restoration	Actions that increase or improve physical habitat conditions or habitat connectivity within the estuary, floodplain, and stream-estuary ecotone.
Instream flow protection and improvement	Actions that increase, improve, or protect water supply and aquifers or conditions that maintain surface and groundwater that contribute to supporting instream flows for fish and other aquatic species and the ecosystems they depend on (e.g., riparian corridor ecosystem).
Water quality improvement (including water temperature)	Actions that improve water quality conditions for fish and other aquatic species and support the ecosystem on which they depend include water temperature, water chemistry, fine sediment, and pollution.
Riparian and wetland habitat restoration	Actions that increase, improve, or protect riparian and wetland habitat conditions that influence channel form and geomorphic processes (e.g., large wood supply), aquatic habitat conditions (e.g., stream shading, water quality), and ecology (e.g., allochthonous inputs).
Invasive species management	Actions that reduce the impact of invasive species on focal fish species, particularly predation by non-native fish (e.g., Sacramento Pikeminnow). Invasive vegetation (e.g., *Arundo donax*), aquatic mollusks, and terrestrial wildlife species are also considered.
Active species management	Actions that improve habitat conditions or productivity of focal fish species through active species management (e.g., beaver reintroductions; hatchery or hatch box program).

Restoration and Conservation Action Categories	Description
Upslope sediment control/management (including streambank erosion)	Actions that decrease sediment delivery rates to streams particularly increased sediment supply caused by man-made infrastructure (e.g., roads), land management activities (e.g., timber harvest), or other anthropogenic disturbance (recreation, increased wildfire activity).
Land conservation and protection	Actions that protect or conserve lands with unique, important, and/or intact habitats to maintain or improve river corridor habitat, preserve natural processes, and/or improve habitat connectivity over 10s-100s year time scale.
Biodiversity protection	Establish conservation targets for state listed species of concern and other important habitats by integrating available data to biodiversity metrics.
Ecosystem services	Protect landscapes that deliver multiple ecosystem services are resilient and likely to persist under future climate conditions.
Upland forest to riparian corridor connectivity	In land adjacent to and or impacting riparian corridors, avoid conversion and advance durable protection measures, such as acquisition, voluntary easements, and less near forested areas. Retain forests to preserve carbon storage value, reduce sediment loads in rivers, cool air temperatures.
Wetland conservation	Connect wetlands to riparian areas, prioritize those with dense vegetation values. Where vegetation values are low, prioritize revegetation, restoration, and connect to riparian corridors between existing protected areas and other core habitat.
Conservation policy	Increase the extent of Wild and Scenic Rivers. Rank potential riparian climate resilience within the Wild and Scenic River areas of the watershed to promote the protection of those areas. Work with management agencies to develop management plans for existing and new Wild and Scenic Rivers.
Conservation for climate mitigation	Focus prioritizations to protect remnant and/or parcels connected to existing protected areas that have low solar radiation values, lower temperatures, and heat mitigating landscape features, especially in Disadvantaged Community Areas. Strategize and engage with local forestry managers to support restoration action in these areas. Recommend revegetation where upland habitat connects to riparian corridors, incorporate Forest Service data from recently burned areas, updated vegetation maps post-fire impacts. Partner with community groups and agencies to recommend priority parcels for flood mitigation acquisition.
Other potential restoration, conservation, and protection strategies	Community outreach/education: Eel River watershed natural history publications. Regulatory: Wild and Scenic Rivers, river and ocean fisheries management, instream flow policy. Improve biotic conditions through nutrient additions and disease monitoring and management.

5 PRIORITIZATION FRAMEWORK

Numerous potential restoration and conservation actions could be implemented in the Eel River watershed. Some are expected to be more effective for achieving Program goals than others. A prioritization process is needed to identify the most important actions and target locations to improve the effectiveness of Program implementation.

An effective approach to prioritize restoration and conservation actions includes a systematic, replicable, and transparent process for making decisions about the efficacy of actions (Beechie et al. 2008, ESSA et al. 2019). A prioritization framework provides structure to complex decision-making in a way that can be easily understood by community members, funders, and restoration practitioners, and can integrate new information throughout the process and result in a more effective and meaningful restoration.

Prioritizing, or ranking, potential actions can incorporate immediate restoration needs in response to disturbances (e.g., wildfires), or they can consider opportunistic projects that require large-scale collaboration among different groups and agencies (e.g., Potter Valley Project decommissioning). As immediate needs are met, priorities will change. Additionally, implementation of actions and ongoing hypothesis-based monitoring will inform adjustments to established priorities depending on how well initial priority actions are performing. In summary, the priority of actions and projects should be revisited regularly.

The prioritization framework described in this Plan defines a process for identifying and ranking critical restoration needs and conservation opportunities (actions). The desired outcome of prioritization for the Program is to identify (1) restoration actions that will recover fish populations and (2) strategic locations for conservation that will protect fish populations into the future. Within this framework, there are separate, yet complementary processes for restoration and conservation action prioritization. The results of the prioritization analyses will be synthesized to develop a comprehensive Action Plan for the watershed, and specific to each of the seven sub-watersheds. The Action Plan will be developed in the next phase of planning for the Program.

Arriving at the outcome of the prioritization process requires several steps in a complex and diverse yet data-poor watershed like the Eel River. Four steps for successfully prioritizing restoration actions have been outlined by Beechie et al. (2008): (1) identify restoration goals, (2) select a prioritization approach, (3) use watershed assessments to identify needed actions, and (4) prioritize actions based on criteria that reflect restoration goals. While the Planning Team has developed a list of restoration goals that would be beneficial for the Eel River (Section 1.2.1), the goals have not been prioritized to determine what would contribute most efficiently to the restoration of species' life-history diversity and abundance. Also, a watershed assessment, which could systematically inform needed actions, has not been conducted. Given the vulnerable state of the Eel River fishery, developing a priority list of actions is needed before undertaking a multi-year watershed assessment. Additionally, a fundamental goal of the Program is to recover abundance and resilience of fish species through the expression of fish life-history diversity. With these constraints and goals in mind, the Planning Team sought to develop an approach for prioritizing actions that can efficiently help inform both questions:

- *What* restoration actions should be taken, and
- *Where* will restoration actions be most effective at recovering fish abundance and resilience?

Additionally, the Planning Team sought to develop a prioritization approach that would integrate conservation action opportunities. The Plan defines conservation as the development of protection measures for areas important for the focal species and goals of the Program. Land use, land ownership, and parcel size will dictate conservation opportunities, while conservation goals (e.g., potential to host biodiversity or provide climate refugia) define conservation priorities among possible parcels. In this way, prioritization of conservation actions proceeds in a slightly different process, with the need to primarily ask the question:

- *Where* are conservation actions needed to protect ecological productivity, preserve biodiversity and provide climate change resilience?

The framework guides how Eel River watershed restoration and conservation action prioritization should occur in the next phase of development of the Program. This section outlines the fundamental concepts of prioritization, including the goals, the types of frameworks that exist, and the scale and resolution of prioritization in the Eel River. The Planning Team reviewed approaches that have been applied to other watersheds, their relevance to the scale hierarchy (Section 2), and their feasibility given data limitations and watershed size of the Eel River. The Planning Team also developed a vision for how action prioritization might be evaluated and revisited in a well-funded program with ongoing monitoring and active management. In summary, this section discusses the following fundamental aspects of an action prioritization framework:

- Spatial planning tools, quantitative population models, and expert ranking approaches;
- Approaches for:
    - Identifying conservation opportunities and locations,
    - Ranking restoration objectives and developing corresponding actions, and
    - Integrating conservation and restoration actions in an Action Plan;
- Data availability and needs; and
- Hypothesis testing within prioritization.

5.1 Review of Approaches for Ranking Restoration and Conservation Actions

The Planning Team considered several different approaches to identify restoration and conservation actions, three of which are discussed here: (1) quantitative spatial planning tools, (2) quantitative fish population models, and (3) data-informed expert ranking approaches. A brief description of these approaches and examples are provided below. All tools and processes use available data to inform action prioritization but require thoughtful and systematic synthesis to recommend high-priority actions and locations. The pros and cons of each approach, along with the suitability of their use for the Eel River watershed due to timing and data availability, informed the Planning Team’s proposed approach for basin-wide action prioritization planning.

5.1.1 Quantitative Spatial Planning Tools

Spatial planning is a key component of conservation and restoration planning because it brings together multiple factors to show how they are connected and highlight similarities and differences across a landscape. The most informative spatial analyses consider multiple scales of data inputs and landscape processes to help meet conservation and restoration goals (Figure 51)

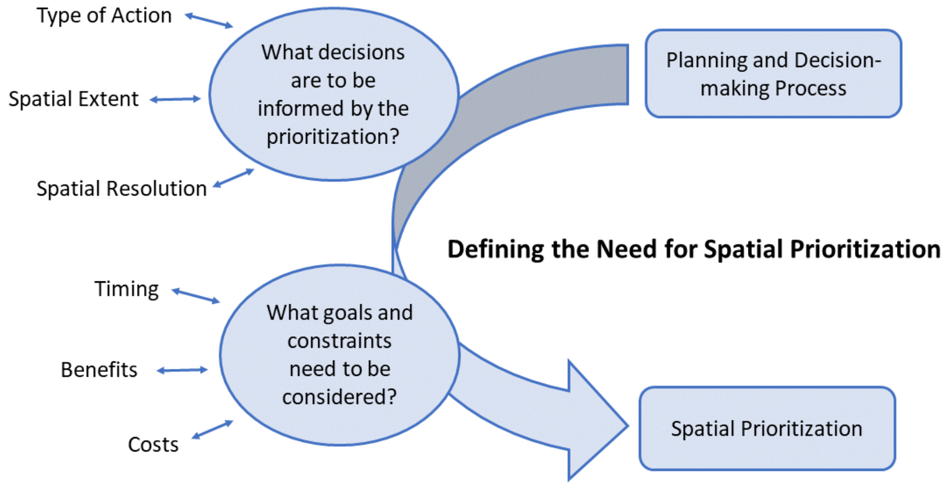


Figure 5-1. Defining the need for spatial data analysis in a restoration and conservation action prioritization process. The process for choosing spatial data and how they will be used for restoration and conservation prioritization. (Adapted from Moilanen et al. 2009)

Spatial analyses help highlight important areas for both conservation and restoration actions within a watershed. Spatial planning tools are best suited to answer the question:

- *Where* are actions most needed?

For conservation planning, it is important to answer the above question first, to identify opportunities on strategic and available lands that can meet the Program's goals (Section 1.2.1). For restoration planning, answering this question may come second, after understanding what factors are most likely limiting fish populations. The same spatial planning tool, with different inputs and rankings, may help with planning for conservation and restoration actions. The Planning Team identified several quantitative spatial planning tools that have been used to inform conservation and restoration planning in other planning efforts. These tools are briefly reviewed below.

Marxan is a Geographic Information System (GIS)-based software that can be used to identify land areas that meet several criteria that are ranked by the user (Ball et al. 2009, Margules and Pressey 2000). Marxan identifies many land areas that fit the criteria that are set to achieve a project's goals. The solutions do not provide a definitive answer for the best land areas but, instead, require that the user consider the resulting highly ranked options. At the watershed level, Marxan has been used in several applications to support management objectives of ecological connectivity, metapopulation persistence and resilience, and biodiversity protection (Daigle et al. 2020). Marxan has been used by EcoTrust and the Forest Service to develop a regional prioritization mapping tool for watersheds in the Pacific Northwest, based on watershed condition, species use, and climate change vulnerability (Ecotrust and Forest Service, 2010). The Nature Conservancy applied Marxan to identify sub-watersheds that protect habitat for deer, salmon, and karst features on the Prince of Wales Island in Alaska (Albert et al. 2008).

Marxan Connect is a GIS-based software in the Marxan family of planning tools, which in addition to analyzing spatial data with conservation targets, can integrate the connectivity needs defined by the user for the planning area. While useful in concept, there are other connectivity planning adjustments that can be made using the basic Marxan software. With Marxan Connect, the connectivity elements are integrated into the algorithm, while with the regular Marxan software, the user has more control to adjust these connectivity calibrations manually (Daigle et al. 2020).

Other spatial planning tools, such as the Miradi method, were used by the Planning Team to initially define the variables and landscape impacts to the focal anadromous species, providing a framework to consider how to make conservation and restoration targets that can later be used as quantitative inputs to algorithm-based planning software, such as Marxan (Carwardine et al. 2009, 2010; Doherty et al. 2018). For example, the Planning Team used Miradi to decide on the granularity of planning processes that would be useful in a large landscape such as the Eel River watershed but did not explicitly set those target percentages for restoration actions in this Plan. The Miradi approach is one of several planning tools that can be used by experts in Phase 2: Prioritization to help decide on quantitative targets for restoration and conservation planning.

5.1.2 Quantitative Fish Models

Another quantitative approach that can inform action prioritization are fish population models. These models rely on basin-wide fish-focused models to make predictions about the types of actions that will provide the greatest benefit to fish recovery. Many of these models require some form of life-cycle modeling, where species survival from one life stage to the next is predicted based on a suite of input data and parameters. Among the various modeling tools, two were considered in more detail for the Program because they have been implemented in other recently completed restoration plans: Ecosystem, Diagnosis, and Treatment (EDT) and Habitat Assessment and Restoration Planning (HARP).

EDT is a river flow and habitat modeling tool designed to help managers weigh the effects of different scenarios on fish population performance (Lestelle et al. 2004, Blair et al. 2009). The EDT model assumes pre-developed relationships between species survival and productivity and the spatial/temporal variation in habitat quality. The model relies on a Beverton-Holt production function, where productivity declines with density dependence, and maximum productivity rate is a function of the environment. One unique aspect of the EDT software is that it explicitly models life-history diversity via “trajectories,” or pathways through the environment. EDT can be used to estimate the number of spawners, intrinsic productivity, and life-history diversity of a population under different restoration scenarios. EDT is a proprietary software (currently owned by ICF International) that has been applied to many watersheds, including streams in the Columbia River Valley, Washington; Puget Sound, Washington; Central Valley, California; and the Scott River watershed, California.

HARP is a similar framework for identifying habitat change and restoration potential in a watershed (Beechie et al. 2021). The HARP model is divided into three steps: (1) a spatial analysis that translates spatial data into habitat conditions, (2) a habitat analysis that creates habitat scenarios under current, historical, or future conditions, and (3) a life-cycle model. Similar to EDT, the HARP model implements life-cycle models that are based on life stage capacities and productivity within a Beverton-Holt curve that assumes density dependence. Sub-basins are modeled as sub-populations within HARP, allowing for a spatially explicit understanding of the effect of restoration on basin-wide populations. HARP has been applied in the Chehalis River basin, Washington; and in the Snohomish and Stillaguamish rivers, Washington.

These two fish models are similar in their need for spatially explicit data that describe habitat condition throughout a watershed. Additionally, they both require professional opinions or predictions about how restoration actions influence habitat quality and quantity, in a way that then directly impacts productivity and survival of salmonids at each life stage. These assumptions are foundational to how the models perform and predict which restoration actions will be most beneficial for restoring salmonids. For example, if it is assumed that large woody debris will have minimal impact on habitat improvement or have a weak linkage to salmonid success, it will be ranked lower as an action. Both fish models also require a set of pre-determined scenarios for evaluation. Neither has been developed for non-salmonid species (e.g., Pacific Lamprey or Green Sturgeon).

Other quantitative models exist to help inform the potential benefit of restoration actions (e.g., inSalmo [Railsback et al. 2021), the Stream Salmonid Simulator (S3) [Perry et al. 2018], and the RIPPLE model [Dietrich and Ligon 2008]). These fish models are not reviewed in this Plan but share the same need for watershed specific fisheries and/or habitat data. However, some of these fish models cover a much smaller spatial scale than is suitable for watershed-wide planning.

After reviewing the function and inputs to quantitative life-cycle models, the Planning Team developed a list of pros and cons about this type of model, broadly. The list was developed to inform the decision about if these fish population models should be incorporated into Phase 2: Prioritization for the Program (Table 5-1).

Table 5-1. Pros and cons of using large-scale quantitative fish population models for prioritizing restoration actions.

Pros	Cons
Provide quantitative predictions for the relative efficacy of restoration actions	Require data-intensive life-cycle models, ideally with basin-specific survival parameters between life stages
Provide spatial explicit information about where restoration actions can improve salmonid populations, if the model is set up to test that question	Require data-intensive predictions on habitat quality throughout the basin
Evaluate complex emergent properties of restoration actions on species' life histories and abundances	Require assumptions on relationships between habitat characteristics and salmonid survival/productivity
Synthesize the effects of restoration on a large spatial scale (e.g., a very large watershed, integrating across smaller sub-watersheds)	May require years to parameterize, develop scenarios, and run models
--	Requires decisions early on about the spatial scale/units of the model, with little flexibility
--	May be difficult to engage the public and many organizations in model development, leading to a lack of understanding how the model works, e.g., it may be perceived as a "black box," with little buy-in outside the core technical team
--	Requires time and funds to develop

5.1.3 Expert Ranking Approaches

Expert ranking approaches entail gathering a group of experts to rank limiting factors for focal species, specific actions, action types, basin-wide stressors, or important sub-watersheds and locations. This "scoresheet" approach can provide a powerful decision support system that provides transparency and flexibility (Beechie et al. 2008, Roni et al. 2013). Recent restoration plans that rely on logic-based approaches (with support from quantitative data) for the region include Salmonid Habitat Restoration Priorities (SHaRP) in the South Fork Eel River and the Integrated Fisheries Restoration and Monitoring Plan (IFRMP) in the Klamath River watershed. Both examples are discussed below.

The SHaRP process, led by the National Marie Fisheries (NMFS) and CDFW, was piloted in the South Fork Eel River watershed. This watershed was chosen because it was considered high potential for continuing to support anadromous salmonids. The SHaRP steering team selected seven focal sub-watersheds at the HUC-12 sub-basin scale based on integrity and risk, optimism and potential, habitat condition, and biological importance. For each sub-watershed, SHaRP gathered an expert panel to identify important limiting factors. The expert panel ranked potential limiting factors (e.g., water temperature and lack of channel complexity) for each life stage of each species within tributary groups. A second set of experts were then gathered to identify restoration solutions for the most limiting factors. The result of the South Fork Eel River SHaRP process is an action plan for each sub-watershed that identifies high-priority treatments and actions along with the reaches and streams for which the treatments would be appropriate.

The IFRMP is a large-scale restoration plan for the Klamath River watershed led by ESSA Technologies Ltd. (ESSA 2023). The IFRMP created a ranking system to evaluate restoration project concepts that were based on number of affected species, the need to improve core performance indicators (ecosystem processes and fish habitat metrics), scale of benefit, and potential for implementation. In a multi-day workshop, IFRMP restoration practitioners, which included members of agencies, tribes, and watershed councils, brainstormed projects that would be evaluated within each sub-watershed of the Klamath River. Projects were then ranked based on the previously defined criteria. The relative importance of each criterion for the final score can be altered in real time by the public on an interactive website to visualize how changes to the criterion would affect ranking of restoration projects.

Expert-based ranking frameworks, such as the SHaRP process and IFRMP, are flexible decision-support tools that can accommodate a range of restoration objectives and criteria. These approaches allow for many people to have a voice, which can improve support of the end results. Depending on the scope of the restoration planning effort, expert ranking can be used to prioritize broad actions (as in the SHaRP process) or more specific project concepts (as with the IFRMP). They are not reliant on proprietary software and can be adjusted and refined relatively easily as projects are completed and lessons about efficacy and cost are learned. On the other hand, the results rely on the expert who does the ranking and the extent of expertise in the basin. Careful planning is advised so that an appropriate group of diverse experts are invited to the ranking process. The pros and cons of using an expert ranking approach are outlined in Table 5-2.

Table 5-2. Pros and cons of using expert ranking approaches for prioritization in restoration planning.

Pros	Cons
Data inputs are tailored to specific watershed or sub-watershed of interest	Ranking process and results may be considered subjective
The ranking process is easy to understand and communicate to many interested parties	A pre-determined list of items are required for ranking (e.g., restoration goals or actions)
Allows for broader participation by constituents, leading to stronger support for the results	Rankings are based on expert understanding, without the ability to game/model how actions might play out
The process can be conducted over a shorter time frame and is much less expensive than a quantitative population model	Unqualified people, or perceived to be unqualified people, may conduct some of the ranking

Pros	Cons
Spatial scale can be refined through iterative ranking exercises (start at larger watersheds, move to smaller sub-watersheds and reaches)	Differences in opinion of the importance of criteria or limiting factors can be difficult to manage in a group setting
Flexibility in the scale of the ranking, which can be of actions or projects, depending on available information and scale of planning	-
Criteria can be weighted in the ranking process	-

5.2 Proposed Approach to Prioritizing Restoration and Conservation Actions

The proposed approach includes the use of both expert ranking and quantitative spatial planning tools described above. The conservation prioritization will rely on a quantitative spatial planning tool and expert-informed conservation targets for the data inputs to the tool (Section 5.2.1). The restoration prioritization requires several steps and will include several workshops and use of spatial planning tools by the Planning Team (Section 5.2.2). After prioritizing conservation and restoration actions in parallel, there will be a need for informed synthesis for both types of actions to develop an Action Plan (Section 5.2.3). The proposed multi-pronged approach considers constraints, such as extensive data gaps in a geologically and biologically diverse watershed, and the need for strategic, rapid action to recover and protect fisheries. The proposed approach will lead to the desired outcome of the prioritization process, which is recommendations for lands that should be conserved, and the type of and locations for restoration actions.

5.2.1 Conservation Prioritization Approach

A program goal (Section 1.2.1) is to “protect and conserve landscape connections between important riparian and upland habitats.” In many cases, an ad hoc approach to conservation, where land is set aside for protection based on logistical reasons, is the normal practice. For example, conserved areas are located where land is cheap or away from populated areas, regardless of biodiversity or landscape connectivity. Conducting formal spatial planning that integrates various desired characteristics of the land, such as biodiversity, presence of focal species, vegetation health indices, presence of wetlands, possibility to provide climate refugia, and connectivity to other conserved lands, can greatly improve the efficacy of conserved lands to support species in a changing world (Jones et al. 2016, Wohl et al. 2021).

To protect important, yet representative, habitats, the Planning Team can use spatial analyses to define core areas for conservation and associated upland areas that currently provide productive habitats for focal fish species. However, species distributions will likely shift across the watershed as the climate shifts (Krosby et al. 2015). Therefore, habitats that species will need to use as climate changes must also be identified and protected with a strategic process (Heller et al. 2015, Lawler et al. 2015).

To meet the Program goal to *protect and conserve*, as described above, the Planning Team developed an approach for conservation planning that leans heavily on quantitative analyses, and expert opinion. Core conservation areas will be identified with a quantitative spatial planning tool—Marxan. The approach, which is a multi-criterion, conservation target and structural connectivity systematic assessment strategy, or Resilience Strategy, is described in detail below:

- Identify desired characteristics for conserved lands,
- Conduct a spatial analysis using Marxan to identify locations that have desired characteristics,
- Convene experts to review and adjust the conservation targets and rerun Marxan as needed,

- Conduct corridor/network planning, (Donald and Evans 2006, Fremier et al. 2015, Haddad et al. 2015); and
- Share results to increase public and community engagement (Chan et al. 2006).

5.2.1.1 Desired Characteristics for Conserved Lands

The conservation approach was built on a set of guiding principles for effective climate resilient conservation planning. In this approach, lands that are conserved will have characteristics that will:

- Protect biodiversity (Eken et al. 2004);
- Adequately represent diverse habitat types in the newly protected areas (Geldmann et al. 2013);
- Provide riparian climate refugia (Dunn and Angermeier 2019, Krosby et al. 2018);
- Provide thermal refugia for aquatic species in the future; and
- Promote protection of lands with multiple benefits.

5.2.1.2 Implementing Marxan

The steps developed to use Marxan for prioritization of conserved areas in Phase 2 prioritization are depicted in Figure 5-2, and are described in detail here.

Landscape, habitat and species data are first integrated into the conservation strategy as spatial data. Each spatial dataset will first go through a thorough review of adequacy and completeness. The data are mapped across the planning area and used as conservation features for defining focal areas for conservation. After the key data variables for the quantitative analysis are decided on, a group of experts decides on the percent of each variable that will be used to derive the conservation solution.

Conservation targets are set within each of the habitat and landscape data variables. For example, conservation targets recommended by the Convention on Biological Diversity are set at percentages based on international expert opinion and scientific reports. Often these target percentages are used as guidelines for local and regional planning. The recommendations outlined by the California Natural Resources Association (CNRA 2022), follow the Convention on Biological Diversity parameters for protecting 30% of California by the year 2030. This recommendation is locally referred to as the California 30x30 initiative. However, simply protecting 30% of California lands and oceans will not meet ensure that conserved lands contain the desired characteristics, as described in above (Section 5.2.1.1). Thus, conservation targets are defined by a group of subject experts to inform the quantitative prioritization process and guide the establishment of a recommended protected area network across the watershed.

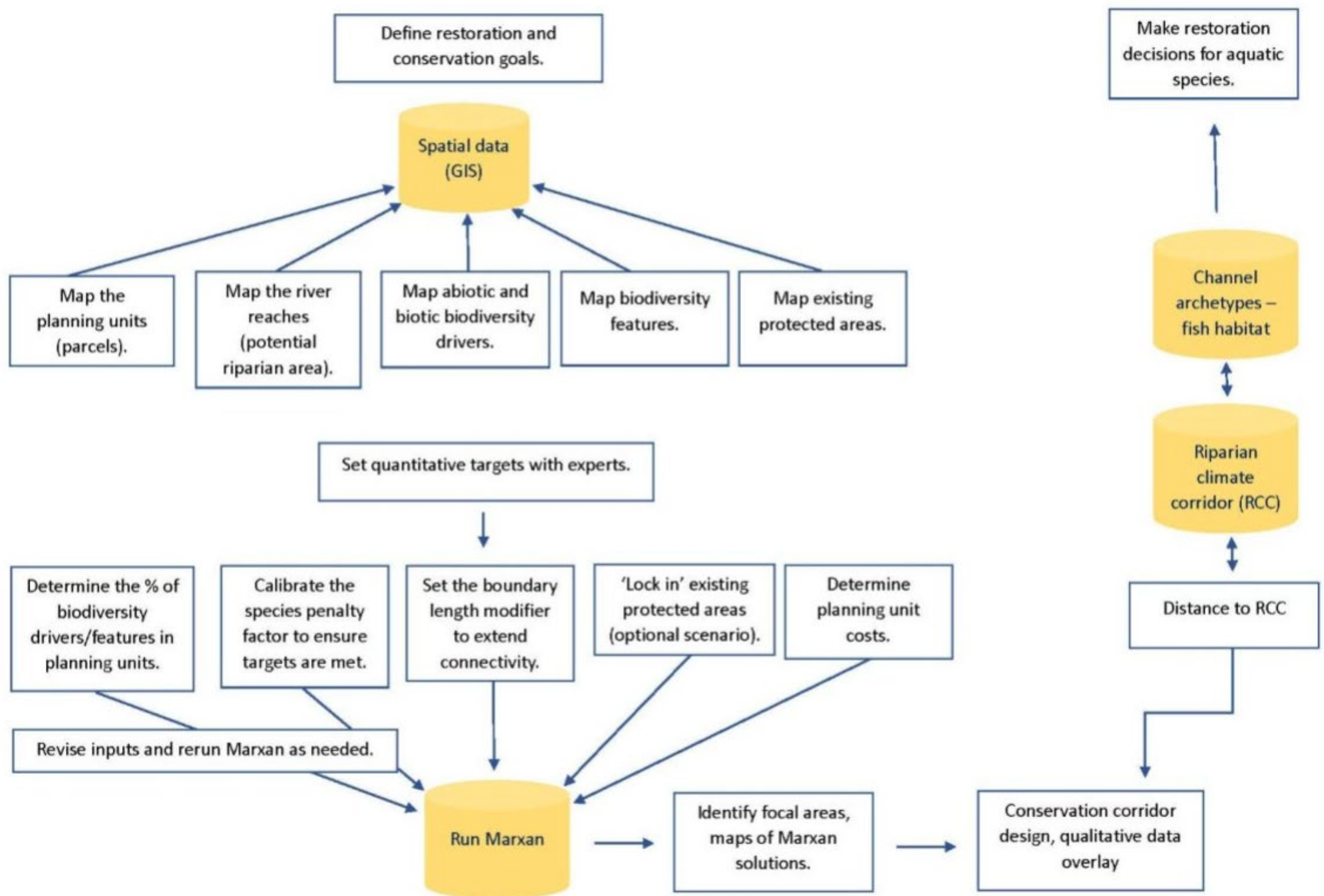


Figure 5-2. Workflow for combining the conservation prioritization strategy with other Eel River data products. The diagram shows the relationship between data inputs, Marxan algorithm model outputs, corridor design, and other data overlay options.

After datasets are integrated and targets are set, Marxan is used to define maps of spatial solutions that meet the conservation and restoration targets for the watershed area.
A review of the Marxan mapped spatial area results will be necessary to ensure the solutions meet the goals of the Program (Serra et al. 2020). The review, conducted by an expert panel in Phase 2 of the Program, will examine the effectiveness and efficiency of the solutions.

- *Effectiveness*: How well the results meet the achievement of the defined analysis goals and targets. To do this, Marxan must be calibrated to adjust the outcome to ensure the targets are met at 100% for the best solutions (Possingham et al. 2000).
- *Efficiency*: How efficient the solutions are at meeting conservation goals within a minimal cost range and with an efficient clumping of sites for land management. To ensure this efficiency of cost and area, the boundary length modifier tool within the Marxan software can be calibrated (Serra et al. 2020).

The result from this first step of implementing Marxan will be a set parcels that are highly ranked due to their characteristics that meet conservation guiding principles.

5.2.1.3 Riparian corridor network planning

A corridor is a general term for a conduit or connecting group of features in the landscape. Connected landscapes are considered as the best strategy for building climate resilience (Zavaleta 2009). To be effective as a habitat corridor, a corridor must be strategically selected for its connective attributes at the watershed scale. These attributes are size > 1 km elevation gradients, degree of fragmentation, availability of habitat per species (many plants cannot disperse at < 20% habitat), climate velocity, species dispersal capacity, and habitat preferences (Groves et al. 2012, Tallis et al. 2021). Corridors must also include prioritized sites for habitat restoration and conservation which incorporate species needs and landscape processes (Anderson et al. 2014, Metzger and Brancalion 2013). Riparian areas provide a natural framework to build connected networks (Salviano et al. 2021, Steidl 2009).

Planning conservation networks around riparian corridors is a natural fit as over time, there has been a preference in land management for preserving riparian forests over more valuable, farmable, or timber harvestable land (Krosby et al. 2018, Pressey and Bottrill 2009, Soule and Terborgh 1999). A simple method to refine corridor design with the goal of improving freshwater protection in a planning area is to extend the protection of rivers to the full length of their flow. This also addresses the need for protecting environmental gradients in the planning area (Nel et al. 2009). The first step to build the connected corridor network is to spatially define, name and number riparian corridors and connective blocks of land between protected areas and riparian corridors.

Marxan is a quantitative planning tool that can provide spatial data–informed connectivity solutions, but it cannot build corridors. To expand on the conservation solutions derived from the Marxan, the Planning Team recommends establishing a conservation corridor network in Phase 2 of the Program, to ensure that basin-wide processes for connectivity are built into the conservation strategy (Davis 2020, Rouget et al. 2006).

To build a representative, conservation corridor network, the Planning Team will consider connectivity elements, such as proximity to existing protected areas, riparian buffers, riparian corridors, connectivity corridors, and climate corridors. To create structural connectivity within the framework, the team will include the connectivity needs of many species and overlaid these with important biodiversity areas and representative landscape resiliency data for environmental gradients known to assist species persistence during climate change.

5.2.1.4 Integration of Marxan solutions and corridor development

Results from conservation planning at the parcel scale will be overlaid with results from the corridor analysis, along with other analyses within the Program, including restoration prioritization at the HUC-12 sub-basin scale (Section 5.2.2) and the channel archetypes (Section 2.2). Additionally, the final step of planning will integrate other spatial planning datasets and analyses such as riparian climate refugia corridor data and block polygons from the California Essential Habitat Connectivity project (Spencer et al. 2010). Additionally, there will be a need to overlay mapped potential riparian area polygons to establish real-world boundaries for the riparian area in the network. This synthesis step will inform the final recommendations for high priority lands and parcels to be conserved and protected.

The results from Marxan prioritization and associated spatial planning in Phase 2 will be used to establish core climate resilient habitat areas of the corridor network. The results will be analyzed by the Planning Team to assess how the prioritized areas meet the Program goal *Protect* defined in Section 1.2.1.2:

- Increase the size of core habitat areas to establish a buffer zone around the core areas;
- Identify potential areas for corridor network expansion into locations of upland habitat;

5.2.1.5 Maps for public engagement in conservation

Maps and visual aids that engage private landowners are integral in sharing the results of the conservation prioritization and providing resources and links for conservation acquisition, easements, and future landowner incentive programs in the watershed. Thus, a final but key task of the conservation prioritization approach in Phase 2 will be to build and maintain a web map and ArcGIS StoryMap with the analysis outcomes clearly described and accessible to interested parties. The mapped conservation parcel prioritization results will have short- and long-term outcomes in the watershed:

- *Short-term Outcome*: An online resource of digitized, dynamic, and interactive maps showing the best options for acquisition of conservation actions or improved protection for parcels that score highly for climate resilience and biodiversity.
- *Long-term Outcome*: Strengthened partnerships between community organizations, participation from Native American Tribes, expanded capacity for community members and Native American Tribes to access information about climate resiliency options for land management and improved livelihood with ecosystem services from protected habitat across a connective watershed riparian climate corridor.

5.2.2 Restoration Prioritization Approach

The order of restoration prioritization can proceed in several ways—prioritizing locations before actions or vice versa (Roni et al. 2013). For several reasons, the Planning Team suggests identifying the restoration objectives and associated actions that are predicted to be most beneficial for focal species, and then conducting the spatial planning of associated locations for each high priority action. The final step will be to rank the combination of actions and their associated most-suitable locations. Identifying the *what* before the *where* will determine the priority objectives for each focal species (Section 4.2) and set the process up to identify actions that meet the Program goal of *restoring life-history diversity* of each species, as a means of restoring fish populations (Section 1.2.1, Section 3). The prioritization process will consider that the focal fish species require the entire watershed, including warm mainstems and seasonal tributaries, to develop diverse life-history strategies that provide population resilience across different water year types. Therefore, in Phase 2, prioritizing restoration actions should begin with a watershed-wide perspective and ask what needs to be done, with the greatest benefit for many species and life-history strategies, before focusing in on smaller sub-watersheds or channel archetypes where those actions will be most suitable.

Within this context, the recommended approach for prioritizing restoration actions requires several steps to arrive at (1) recommended restoration goals and actions and (2) sub-watersheds that will benefit most from those restoration actions. Together, these steps will answer *what* restoration actions should be prioritized, and *where* should they be done. The recommended restoration prioritization framework includes expert-based rankings and quantitative spatial planning tools. A multi-step, logic-based ranking conducted by watershed experts and informed by the best available data and species conceptual models (Section 3) will be used to identify high priority restoration actions in Phase 2. The results of expert ranking will be combined with spatial planning tools to inform where restoration actions should be conducted. This multi-pronged approach will enable efficient prioritization and will use collective understanding to characterize habitat conditions and fish populations in much of the Eel River watershed. This approach should be considered a starting point and does not preclude developing quantitative population models and/or watershed assessments to guide restoration actions in the future.

5.2.2.1 Broad and Specific Restoration Actions

Before describing the restoration action prioritization steps in detail, it is important to understand the proposed scale of recommended restoration actions for the Action Plan that will be developed in Phase 2. Two levels of resolution should be prioritized, each with slightly different steps: *broad actions* and *specific actions* (Figure 5-3).

- *Broad actions* are beneficial for focal species and life histories in many locations throughout the watershed. One example is the addition of large wood to create habitat complexity. For broad actions, there is a need to prioritize not only *what* actions are most likely to achieve restoration goals, but also *where* each action will be most beneficial in terms of benefits to focal species and life histories. Following the spatial structure (Section 2), broad actions will be associated with certain channel archetypes and HUC-12 sub-basins. Local landowners, restoration practitioners, and watershed restoration groups can use these broad actions as a starting point to develop more specific actions and determine their locations. The Plan does not intend to propose specific locations; rather, restoration practitioners should determine the exact site and actions given their knowledge of the area.
- *Specific actions* are those that are inherently associated with a geographic location and are anticipated to have an outsized benefit on the watershed's ecological and geomorphic function. For example, future dam decommissioning in the upper Eel River watershed is anticipated to have long-term benefits for downstream hydrology and geomorphology and to restore access to headwater habitat for spawning and rearing. Another example may be addressing a known major source of fine sediment from a landslide or road failure that is degrading water quality and downstream habitat (choking spawning gravels or filling in deep pools).

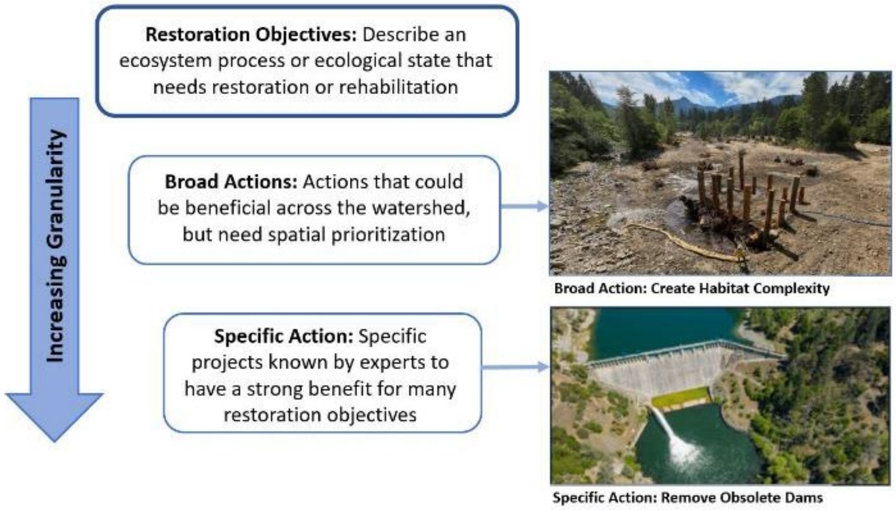


Figure 5-3. Conceptualization of how broad and specific restorations address restoration objectives. *Broad* and *specific* actions will be considered separately in restoration action prioritization.

5.2.2.2 Steps of the Restoration Prioritization Approach

The following steps are proposed for prioritizing restoration actions and locations (Phase 2) during a series of workshops and analyses:

- Rank habitat and landscape restoration objectives for their ability to achieve fish population and fish life-history diversity goals (Section 4.2) (Workshop 1);
- Identify broad restoration actions that will address objectives (Workshop 2);
- Solicit professional opinion to identify specific restoration actions that will meet objectives (Workshop 1and 2);
- Conduct spatial analyses to determine where broad restoration actions are most needed and most appropriate (Planning Team); and
- Rank broad and specific restoration actions (separately) for their predicted ability to recover fish populations, based on cost, feasibility, and ability to address underlying stressors and reestablish natural watershed processes (Workshop 3). At this stage, all restoration actions (broad and specific) will be associated with locations where they are predicted to be most beneficial and suitable, and that information will be part of the ranking.

These steps are depicted in relation to conservation prioritization in Figure 5-4 and are described in further detail in the following sections.

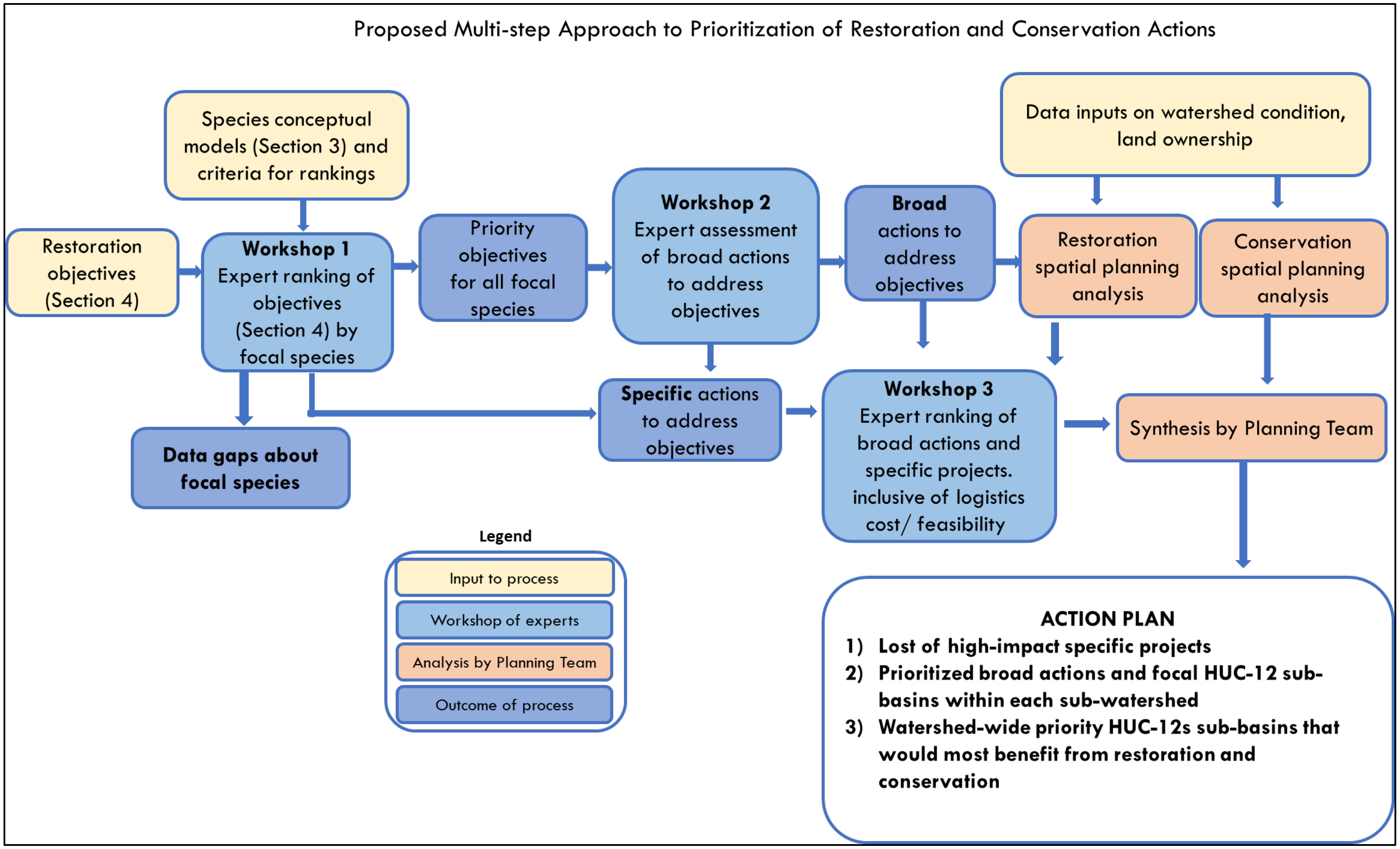


Figure 5-4. Proposed restoration and conservation action prioritization framework that integrates both expert ranking and spatial planning tools. The outcome for this multi-pronged approach is an Action Plan with guidance on how to proceed with restoration and conservation. The outcomes of the Action Plan need to be revisited with ongoing lessons learned from implementation and monitoring.

Workshop 1: Rank restoration objectives and develop specific restoration actions

- *Goal*: The goal of the first workshop is to rank habitat and landscape objectives (Section 4) based on their importance for recovering abundance and resilience of each focal species. The discussion of this workshop should focus on the *need* for restoration and perceived importance of objectives. Feasibility of associated restoration actions will come later, in Workshop 3.
- *Experts at the Table*: People with an on-the-ground understanding of fish populations in the Eel River, including agency and Tribal biologists, local citizen scientists, academic scientists, and watershed council members. Experts plus facilitators (n= 15–20).
- *Process:* The life cycle and life-history strategies of focal species will be used as the basis for discussion. Species conceptual models and channel archetypes will be used to construct scenarios (combinations of life history strategies and natal habitats) that the group walks through to discuss limiting factors and data gaps for each focal species. The group will walk through 3–5 scenarios for each species (total of 20–25 scenarios). Each scenario will be developed by beginning at one type of natal stream (channel archetype, Section 2.2). The group will then discuss the life-history strategies that arise from fish that are born in that archetype, guided by species conceptual models (Section 3). The discussion will focus on habitat limitations in the various habitats that are encountered for life-history strategies originating from that archetype. Data gaps will also be noted. As the discussion progresses, data gaps, such as whether a certain life-history strategy exists or whether a habitat type is impaired, will be noted. There will also be opportunities to note high-impact specific restoration actions that continue to arise in discussion of the strategies.

  After discussion of the species' life-history strategies and factors limiting the recovery of each strategy, each expert panel member will rank the habitat and landscape objectives (Section 4, Appendix E) by level of importance. Their ranking will be guided by pre-developed criteria and informed by the previous in-depth discussion. After ranking is conducted, Planning Team members will collect and summarize answers. At the end of the workshop, participants will have an opportunity to discuss the rankings to understand if and why there are outliers in the rankings.
- *Outcomes*:
  - Top 3–5 most important (priority) restoration objectives for each species.
  - Top 3–5 most important (priority) restoration objectives for all species together.
  - List of specific high-impact specific restoration actions.

Workshop 2: Identify broad actions to meet priority objectives

- *Goal*: The goal of the second workshop is to identify broad restoration actions that will address the priority objectives identified during the first workshop. Specific restoration actions will also be noted. This workshop will reference other actions plans in the Eel River watershed (e.g., SHaRP and the Eel River Action Plan) to ensure that their recommended restoration actions are integrated with the ones of the Program.
- *Experts at the Table*: Restoration practitioners, restoration design engineers, fish and riparian biologists. This group will need to have a strong understanding of real-world implementation of restoration actions that work to meet certain restoration objectives, which differs from the need for fish ecology expertise in the first workshop. Experts plus facilitators (n=15-20).

- *Process*: For each prioritized restoration objective from Workshop 1, Workshop 2 participants will brainstorm broad restoration actions most likely to achieve the objective. The broad restoration actions described in Section 4 and listed in Appendix F will be used as a starting point. Each broad restoration action will also be categorized by whether it is needed to restore watershed processes, restore habitat structure, or both. That information will be used as criteria for the ranking of broad actions in Workshop 3. Approximate relative costs for implementation will be estimated for restoration actions for each objective. Each restoration action will also be associated with the appropriate channel archetypes.
- *Outcomes*: Actions that address each high-priority restoration objective.

Planning Team Task: Conduct spatial analyses to identify priority locations for broad restoration actions

- *Goal*: The goal of spatial analyses is to identify *where* broad restoration actions should occur within the Eel River watershed, given that there are likely many locations that would benefit from restoration actions. The spatial analyses will identify the HUC-12 sub-basins that would provide the greatest benefit from broad restoration actions due to (1) the potential to benefit a high number of species and life-history strategies or an unusual but important life-history strategy, (2) historical land use and the estimated current state of habitat degradation, and (3) other factors influencing where priority broad actions are most appropriate to implement.
- *Experts at the Table*: Planning Team
- *Process*: Spatial analyses will be conducted by members of the Planning Team and will include several components. The first component will be to use a simulated annealing algorithm in Marxan software to identify high priority HUC 12 sub-basins throughout the entire Eel River watershed. The second component will be to layer additional suitable spatial datasets or analytical products onto the Marxan outputs that provide context to inform where each broad restoration action should be implemented. For example, if beaver reintroduction is a highly ranked broad restoration action, then an output from a beaver intrinsic potential model would be highly informative for identifying the most suitable HUC-12s for beaver reintroduction. The outcome of the ranking of the broad restoration actions in Workshops 1 and 2 will dictate which datasets should be considered for additional spatial analyses in this step of the process.

  The processes for running Marxan to inform where restoration actions are most needed follows:

  1. Identify and gather appropriate data input layers (Table 5-3).
  2. Develop a weighting/importance ranking for data layers for use in Marxan.
  3. Use Marxan to establish multiple priority outcome sets of parcel solutions using different percentage targets for all focal species. These targets should be initially set at 10% for all focal fish species and then modified up to <100% after each scenario is developed. HUC-12 sub-basins selected in all Marxan processing will be considered a high priority location that would provide the greatest benefit from restoration actions. Watersheds selected in fewer runs will have a lower priority.
  4. Watersheds with conditions that are less conducive to focal species habitat are scored as a lower priority for restoration and conservation actions. For example, these watersheds may have poor relative condition, high relative climate change vulnerability, lower overall species richness, and less likely to support a diversity of life-history strategies of focal species (Section 3).

5. After all scenarios are created, resulting data layers will be merged and combined to rank the sum of the number of times any given sub-basin is selected for all model runs and used to create categories of the degree of relative prioritization.
6. Finally, use a decision table to view and categorize the results of the iterative Marxan analysis. For example, Table 5-3 shows the representation of the number of times a watershed is selected, along with the associated category of relative importance defined at approximately 20% per category.

Table 5-3. Example relative importance ranking for Marxan prioritization analysis results for the 113 HUC-12 sub-basins in the Eel River watershed.

Number of times a planning unit (HUC-12 sub-basin) is selected	Relative importance ranking
1–25	Low priority
26–50	Medium low priority
51–75	Medium priority
76–100	Medium–high priority
101–113	High priority

- *Outcomes*: A list of HUC-12 sub-basins that are most suitable for each high-priority restoration action (developed in Workshop 2). There will likely be an overlap in the highly ranked HUC-12 sub-basins among the restoration actions.

Workshop 3: Rank broad and specific restoration actions

- *Goal*: The goal of the third workshop is to quantify expert opinion to rank broad and specific restoration actions based on criteria related to impacts on fish populations, feasibility, and cost. This ranking will be based on the synthesis of the previous two workshops and the spatial analysis (HUC12 sub-basin rankings using Marxan) by the Program Team.
- *Experts at the Table*: Participants from Workshop 1 and 2, including restoration practitioners, restoration design engineers, fish and riparian biologists, fluvial geomorphologists. 25–30 experts plus facilitators.
- *Process*: Each priority restoration action will be discussed for potential impact to fish populations and implementation feasibility and costs. Experts will be given a score sheet to rank each broad and specific restoration action. The final score/ranking of each restoration action will be an average of all the scores.
- *Outcomes*:
  - A ranked list of broad actions and the high priority HUC-12 sub-basins that are associated with each action, as identified from spatial analyses.
  - A ranked list of specific restoration actions.

5.2.3 Developing a Phase 2 Action Plan for Conservation and Restoration Actions

The workshops and spatial analyses will produce a ranked list of high-priority broad and specific restoration actions and a ranked list of high-priority conservation actions. To develop the Phase 2 Action Plan, the rankings will need to be synthesized and a cross-comparison of restoration and conservation priorities will need to be developed. If there is a sequence that would provide the greatest benefit for restoration and conservation actions, that order will be identified. For example, for some watersheds, it may make sense to remove a significant fish passage barrier before conducting habitat restoration upstream. For each HUC-12 sub-basin, a list of priority broad actions will be synthesized based on the species presence, composition of channel archetypes present, and other characteristics of the HUC-12 sub-basin. At this step, there will also be a need to cross-reference other restoration plans in the Eel River watershed. For example, specific actions developed by the SHaRP should be considered and referenced. The Planning Team expects that the Action Plan will contain other components beyond the priority recommended restoration and conservation actions. In total, the components that may be included in the Action Plan include the following:

- A ranked list of high-priority broad restoration actions and HUC 12 sub-basins where they will be most effective at helping achieve restoration goals,
- A ranked list of specific “grand slam” restoration actions for the Eel River watershed,
- A ranked list of conservation actions for the Eel River watershed,
- Recommendations for the next phase of prioritization by the Program,
- Recommendations for the development of broad restoration actions into site-specific projects, and
- Recommendations for continuing coordination with monitoring and assessment in the Program.

5.3 Data Availability and Needs

The proposed restoration and conservation action prioritization framework will require many data layers to inform spatial planning analyses. Table 5-4 summarizes data layers gathered and expected to be included in the spatial planning. Table 5-5 summarizes additional datasets used to refine the spatial planning interpretation. Some of the layers and datasets may also be presented to workshop participants to inform ranking and development of actions. The compilation of data layers to date focused on data available at an appropriate scale. Some data inputs will be refined for use in the framework. The data presented at the parcel scale will be used mainly for conservation spatial planning. Additionally, spatial planning will lean toward using fewer, more informative layers, at the top of the table, for the quantitative Marxan runs, with the outcomes being informed by additional layers. Data layers at the parcel scale will primarily inform conservation. In the absence of a formal watershed assessment, some data layers will broadly inform watershed condition (e.g., land use history will inform the likelihood impaired sediment transport and altered canopy cover). Data layers listed as “additional data” will likely not be used in quantitative Marxan runs but may be used to inform outputs or for planning of restoration actions.

Table 5-4. Data layers and analyses that may be included in spatial planning for restoration and conservation and their availability at corresponding spatial scales.

Analysis scale	Spatial data and analyses
Watershed	Land use type
	Land use history
	Contemporary canopy cover
	Fire risk
	Biodiversity of terrestrial and aquatic species
Parcel	Riparian thermal refugia
	Land ownership type
	Protected area status
	Vegetation density
	Connectivity—proximity to existing protected areas
	Biodiversity—terrestrial and aquatic
	Resilient lands index (TNC)
	Low solar radiation
Channel	Fish species distribution
	Life-history diversity potential
	Channel archetypes
	Migration barriers
	Water temperature regime
	Flow impairment/diversions

Table 5-5. Additional datasets that may be layered on top of the spatial planning analyses to inform the ranking and sequence of restoration and conservation actions.

Social/Political Data	Disadvantaged communities
	Social and recreational potential
	Existing restoration projects
	Tribal lands
	Privately owned lands
Physical and Ecological Data	Geology and Lithology
	Streamflow regime
	Geomorphic outliers, such as wide, low-gradient floodplains
	Wetland presence and area
	Channel confinement
	Floodplain connectivity
	Riparian buffer area
	Vegetation condition
	Pikeminnow presence/absence
	Beaver potential
	Sediment wasting events
	Proxies for food productivity
	Large wood density
	EPA healthy watersheds data

5.4 Hypothesis Testing within Prioritization

The prioritization process that will unfold as described above will reflect the current understanding of the Eel River watershed. The process integrates multiple information sources, including a historical understanding of the watershed (e.g., fish populations, impairment levels, land use), the contemporary understanding of focal species' life-history diversity (those which are expressed or are no longer expressed) and leverages the collective knowledge of watershed experts to make prioritized recommendations of what restoration and conservation actions are most likely to recover the watershed and meet the Program Goals (Section 1.2.1) and restoration objectives (Section 4). Thus, the prioritization process described above will imply a series of hypotheses about the ecological response to environmental change that will create the largest directional change toward the Program goals. For example, the Planning Team's current understanding suggests that non-native predators are very detrimental to the survival and life-history expression of juvenile salmonids. Preliminary results from pikeminnow suppression and associated studies in the South Fork Eel River suggest low mainstem survival of migrating juvenile salmonids between April and June, with mortality higher in certain reaches compared to others. However, more work is needed to understand the mechanisms of mortality (direct predation or habitat mediated impacts), the impacts to life-history diversity, and the most effective mechanisms to reduce these pressures on juvenile salmonid survival. Because of the limited information around restoration actions in the Eel River watershed, the prioritized actions will be presented as hypotheses that are grounded in the current understanding of the ecosystem. In the scientific method, after hypotheses are developed, they should be tested experimentally or with data collection. The restoration prioritization approach that is for Phase 2 should be treated similarly.

The prioritization approach can be tested through both data collection and experimental designs at different scales in the watershed. The hypothesis testing can be evaluated at two scales: (1) project-level and (2) program-level (population response). At each scale, the prioritization process will interact with the Program monitoring and assessment (Section 7). At the project-level, data can be collected at a project site before and after implementation to collect basic variables around fish presence or absence, water temperature, predator presence, invertebrate productivity, or focal species survival (or any other specific mechanism the project is intended to address). Hypothesis testing around individual projects answers how effective actions can be at a local scale. However, because the Program goals are to recover focal species at the population level and thus demands evaluation at the larger program-level. To test the hypotheses of the prioritization at the watershed scale, the Program should lean on program-level monitoring (Section 7) to determine whether the culmination of multiple actions across the watershed are effective.

Over time, the Program should use this hypothesis framework to (1) determine whether the prioritization process was effective; (2) update the prioritization process with additional information and data; and (3) update the process to determine new actions or locations where restoration and conservation could be most effective. The prioritization process described here or the suggested actions or locations should not be treated as static or fixed, rather it is a dynamic process that interacts with the understanding of the watershed and should be updated as hypotheses are tested, and data are collected. Adoption of the hypothesis testing approach in a large and complex system such as the Eel River will improve the likelihood of recovery and long-term resilience and provide vital information for other restoration and conservation programs.

5.5 Next Steps and Future Refinement of Restoration and Conservation Action Priorities

Additional preparation will be needed to implement the proposed process for prioritizing restoration and conservation actions process. The next steps for each workshop in the planning process follow:

- Develop a detailed agenda,
- Write and test out guided questions,
- Refine datasets that will be presented to workshop participants as background,
- Develop criteria for ranking restoration actions and objectives, and
- Create and invite a list of attendees.

Some next steps for the spatial planning analyses include the following:

- Refine input data layers,
- Develop missing, critical data layers,
- Develop quantitative target percentages for ranking the data layers in Marxan,
- Map the riparian corridors using the potential riparian area data set, and
- Prioritize among the riparian corridor segments to highlight sections for proposed restoration and conservation actions.

The proposed multi-pronged restoration and conservation action prioritization framework developed by the Planning Team is meant to be a first iteration that can proceed quickly to inform rapid and strategic restoration and conservation actions. Quantitative population models have been very helpful in providing mechanistic predictions for the efficacy of restoration actions in other watersheds if the data is available to support these models. As monitoring data in the Eel River continues to be generated, it may become feasible to develop a quantitative fish population model for the Eel River watershed. The Planning Team supports working toward using a quantitative fish population model and suggests that the feasibility of applying a quantitative fish population model be revisited in 3 to 5 years. Additionally, because future monitoring (Section 7) will inform the efficacy of restoration and conservation action types in the Eel River, the monitoring and assessment results should be regularly reviewed and used to update priority restoration and conservation actions priorities.

6 PROGRAM MANAGEMENT FRAMEWORK CONSIDERATIONS

Because of its size, geographic diversity, and disproportionate amount of private land ownership, the Eel River lacks a central entity or agency to oversee and coordinate resource management and restoration activities across the watershed. Without centralized coordination, the numerous agencies, Native American Tribes, and non-profit organizations working throughout the watershed to restore the Eel River ecosystem and its native fish populations often focus on their own individual mandates and objectives and miss opportunities to integrate, prioritize, and focus available resources to achieve a collective vision and goals. The purpose of Program is to implement restoration and conservation actions that achieve the Program's vision and goals (described in Section 1.2.1). To achieve this purpose, a Program Management framework needs to be developed and implemented. In this section, based on experience in other programs with similar vision and goals, the Planning Team recommends a governing and administrative organization (i.e., a management framework) along with a Program Management body that can successfully implement the Program.

A management framework can range from simple, well-defined efforts (e.g., led by one person), to large, complex organizations for large-scale efforts, such as the San Joaquin River Restoration Program (SJRRP 2007) and web Trinity River Restoration Program (USFWS et al. 2000). The larger and more complex the ecological restoration effort (including diversity of participants), the larger and more complex the management framework will likely need to be. Larger management frameworks will also require stable and substantial funding to operate successfully. To address the unique characteristics and needs of the Eel River watershed, and to succeed in the long-term, the appropriate scale and organizational structure needs to be defined at the start, be embraced by the various entities who will participate in the Program's development and implementation and be flexible to adapt and evolve as needed. Recommending a management framework for the Program is a critical step and is dependent on assumptions about the scale and stability of future funding sources.

The Planning Team considered a range of potential management frameworks based on other large-scale restoration programs in the western United States and recommends a management framework based on the current understanding of management needs and potential future funding strategies that may become available, at least to initiate the Program. For this section, "management framework" is defined as initial ideas on how the Eel River restoration framework would be structured and implemented, including funding options, Program structure, roles and responsibilities of participants, topical extent, spatial extent, and linkages to Section 7, *Monitoring and Assessment Framework*, and Section 7.3, *Monitoring and Assessment Process*. Given the scale and complexity of the Eel River watershed, the Planning Team assumes that the future Program Management body will require a robust management structure that is commensurate with other large-scale restoration programs (such as those for the Trinity River and the San Joaquin River). Therefore, this section focuses on a potential management framework for implementing larger-scale ecological management framework considerations (Section 6.1) and assumes that a longer-term and stable funding source can be developed to support this type of ecological management framework for the Eel River (Section 6.2).

6.1 Components of an Ecosystem Management Framework

A large-scale ecosystem management entity should include the following core functions:

- Governance
- Program Management
- Science
- Planning
- Implementation
- External Review

Most large-scale restoration Program Management entities have similar structures and components as shown in Figure 6-1. Similar to a well-functioning government, the structure and function of a restoration program should be developed to provide a transparent decision-making process, have checks and balances to ensure transparency, make informed decisions, allow the Program to adapt based on learning and changing conditions (i.e., improve effectiveness), and share information with interested participants. External review and public outreach are key components of a successful program, and while external review and public outreach are common features of large-scale restoration programs, they are not universal. The Program should also be as simple as possible to meet its needs and be flexible and adaptable over time as participants change, the scientific understanding improves, and implementation approaches evolve. Finally, to best achieve its goals, the Program also needs to be implemented as efficiently and cost-effectively as possible and maintain participant and public support over time.

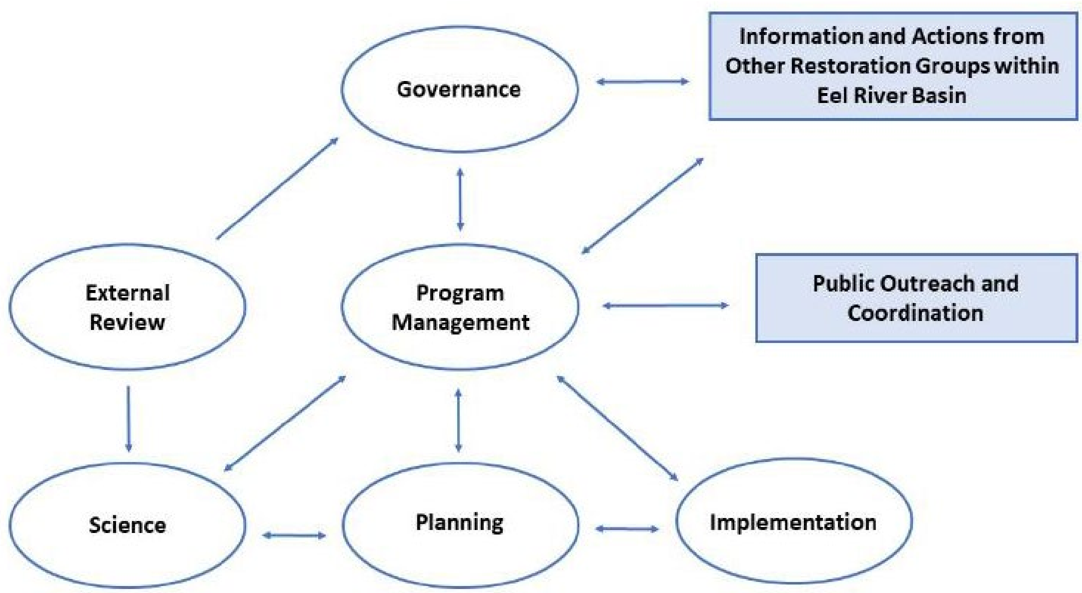


Figure 6-1. Core components of a successful large-scale restoration program.

The components shown in Figure 6-1 are discussed in the sections below using the following organizational structure:

- General overview of role and function of the management framework component;
- Lessons learned from other large-scale restoration programs that should be considered for the management framework; and,
- Recommendations of role and function of that component specifically for the management framework.

Within this management framework, different “bodies” perform specific roles within the components of the framework (e.g., Governance body). The initial recommendations for the Program organizational chart are summarized in Section 6.2.

6.1.1 Governance

The role of Governance is primarily programmatic-level decision-making and strategic planning. Decisions include administrative decisions (e.g., funding and staffing) and implementation decisions (e.g., approving conservation and/or restoration projects and monitoring efforts) that involve allocating staff or funding. Strategic planning decisions include coordination with other agencies and groups, project prioritization and sequencing, staff/resource allocation and prioritization, and other large-scale planning efforts. The participating individuals in the Governance body must have the authority to make decisions on behalf of their organization, otherwise the Governance role will be less efficient and effective if those decisions need to be approved by higher-level supervisors. To build confidence and trust in Program Governance among partners, agencies, and the public, decisions should be transparent and informed by the best possible information. Providing this information to the Governance body is a critical function of Program Management body (described below). Strategic planning and management action decisions made by the Governance body can then be delegated to the Program Management body for implementation.

Several of the authors of this Plan have participated in large-scale restoration programs that are useful examples to consider for assessing strengths and weaknesses in developing a management framework (Table 6-1).

Table 6-1. Select comparable large-scale restoration programs in the western United States that can inform a potential management framework.

Program	Governance and Management Structure	Notes
Trinity River Restoration Program	Governance conducted by the Trinity Management Council, consisting of eight county, state, federal, and Tribal representatives. Program Management conducted by agency staff, and some tasks conducted by agency staff, but most tasks contracted to agencies and Native American Tribes.	• Members of the Trinity Management Council are compensated by the organization they represent, and administrative funding is also provided to several of Trinity Management Council entities. • Governance does not include members of the public or NGOs. • A citizen's advisory group (now disbanded) governed by FACA provided input to the Trinity Management Council but had no Governance responsibilities. • Agency staff is responsible for Program Management, and personnel issues are often hampered because of the lack of timely resolutions to problems. • Agency and Tribal contracting discouraged periodic changes to monitoring and program implementation, limiting quick responses and the initiation of new work to lessons learned. • An SAB intermittently advises the Trinity River Restoration Program, and several programmatic reviews of Governance and Program Management have been conducted. • Very few competitive RFPs have been released due to annual budget inflexibility. • Although adaptive management was intended to be a key component of the program, it had received limited application.
San Joaquin River Restoration Program	Governance conducted by implementing agencies (Reclamation, USFWS, NMFS, CDFW, and DWR), with implementation advised by a Restoration Administrator and a TAC hired by settling parties (Friant Water Users and NRDC coalition). Program Management is conducted by agency staff, and nearly all program tasks are conducted by agencies.	• Implementing agencies are compensated as part of normal salary and congressionally authorized funding. • Governance does not include members of the public or NGOs (no citizen's advisory group governed by FACA). • Program Management is conducted by agency staff, and personnel problems have been limited. • No SAB is included in an advisory role, although the Restoration Administrator and TAC perform some aspects of the advisory role to Governance, Program Management, and Science. • Agency staff conducting work has often resulted in high costs and long delays that cannot be corrected by program staff. • The program has some opportunity for adaptive management, but little very little structure adaptive management experiments have been conducted to date.

Program	Governance and Management Structure	Notes
Platt River Recovery Implementation Program	Governance Committee consists of state and federal agencies and water users. Program Management is contracted to consultant, and many tasks are subcontracted through competitive bids.	• Governance Committee members are compensated as part of normal salary. • Governance Committee does not include members of the public or NGOs. • Program Management by consultant enables rapid corrections by Governance Committee. • Governance Committee and Project Management contractor staff can facilitate rapid correction of consultant work as warranted. • The program has a strong focus on adaptive management.
Klamath River Renewal Corporation	Non-profit corporation is governed by a board of directors consisting of up to 15 members from California, Oregon, Yurok Tribe, Karuk Tribe, Klamath Tribe, and NGOs. Program Management is conducted by six staff members from the Klamath River Renewal Corporation, and most tasks are subcontracted through competitive bids or Tribal agreements.	• Board members are compensated by corporation. • Strong participation in Governance includes Native American Tribes, states, and NGOs. • Because Program Management is staffed by the Klamath River Renewal Corporation, the board of directors can facilitate rapid correction as warranted. • Board of directors and Klamath River Renewal Corporation staff can facilitate rapid correction of contractor work. • Advisory committees engage as needed.

Notes: CDFW = California Department of Fish and Wildlife
DWR = Department of Water Resources
FACA = Federal Advisory Committee Act
NGO = non-governmental organization
NMFS = National Marie Fisheries Service
NRDC Coalition = Coalition of environmental NGOs led by Natural Resources Defense Council
Reclamation = U.S. Department of the Interior, Bureau of Reclamation
RFP = Request for Proposal
SAB = Science Advisory Board
TAC = technical advisory committee
USFWS = U.S. Department of the Interior, Fish and Wildlife Service

Based on the Planning Team's experiences with the large-scale restoration programs listed in Table 6-1, the Planning Team recommends the formation of a non-profit corporation to govern and implement the Program based on the model provided by the Klamath River Renewal Corporation. The primary rationale for this recommendation is that a non-profit corporation will likely provide the following benefits relative to an agency-led Governance structure:

- Greater transparency in decision-making and disclosure of financial information (thus facilitating the public trust);
- Ability to actively pursue funding for Program implementation from both public and private funding sources;
- More effective and efficient responsiveness to management and implementation based on lessons learned;
- More flexibility to pursue real estate transactions, such as conservation easements and land purchases;

- Greater ability to incorporate public input into decision making (does not require a FACA-chartered citizen's advisory group); and
- More control in addressing performance challenges with staff and contractors.

One of the primary challenges with a non-profit corporation, rather than an agency-led Governance structure, is how state and federal agencies can best interact with a non-agency entity when confronted with regulatory and resource management issues. This interaction could be accomplished via regular coordination (quarterly meetings) between an executive director for the Program and agency managers on policy issues, followed by regular coordination with agencies within the Science and Implementation bodies for resource management and regulatory issues. In summary, initial recommendations for the Governance body are as follows (Figure 6-2):

- Form a non-profit corporation to govern and manage the Program similar to the Klamath River Renewal Corporation.
- Empower the new non-profit corporation to hire a small group of staff (approximately 5 to 7 initially) to manage the Program, discussed further in Section 6.1.2.
- Establish a board of directors, of up to 10 members, to govern the Program. The board directors likely cannot include staff from state and federal agencies, but it could include members of Native American Tribes and representatives from counties, NGOs, and the local watershed. The board of directors would be responsible for guiding and approving the following:
    - Program implementation priorities
    - Annual program budgets
    - Requests for proposals (RFPs) and contracts
    - Hiring an executive director and Program staff.

6.1.2 Program Management

The role of the Program Management body is to implement the decisions made by the Governance body and conduct the day-to-day Program operations, including tasks associated with administering the Program, hiring and managing Program staff, coordinating with partners, overseeing project design, implementing and monitoring projects, overseeing Science and research, conducting public outreach and education, coordinating external review of Program Science and management actions, and providing information to the Governance body for discussion and decision-making. The role of individuals within the Program Management body is to provide efficient implementation of the directives of the Governance body and to provide objective science and management information to the Governance body to enable well-informed decision-making.

Common challenges with Program Management include the ability to make timely staffing changes and adjustments to Program actions when needed. A non-profit corporation can be structured to ensure nimble responses can be made when changes to staffing and Program actions are needed. The Planning Team recommends hiring an executive director to oversee implementation of the Program, execute policy, and make management decisions. As the primary conduit of information between the board of directors and Program staff, the executive director would also be responsible for the following:

- Recruiting and making hiring recommendations for Program staff;
- Coordinating with external entities, disseminating information, and conducting public outreach;

- Coordinating with a Science Advisory Board (SAB) and conducting external review;
- Overseeing and submitting annual budgets to the board of directors for review and approval;
- In coordination with the Public Information Officer and Tribal Liaison, reporting on progress made toward reaching Program goals to the board of directors, regulatory agencies, Native American Tribes, media, and the public; and
- Assisting the board of directors with fundraising and pursuing grants.

The Planning Team also recommends hiring a chief financial officer/controller/contracting officer who would be responsible for the financial management of the non-profit corporation and the primary contracting for monitoring and restoration projects. Members of the Science and Implementation bodies would assist the contracting officer as a technical representative for monitoring and restoration contracts.

Lastly, within the Program Management body, the Science, Planning, and Implementation bodies are key components to a successful Program, as discussed further below.

6.1.3 Science

The key role of a Science body within a large-scale restoration program is to provide decision-makers with the best possible information to inform their decisions in a way to achieve program goals in a timely and cost-effective manner. Effective science for a large-scale restoration program must balance several challenging influences:

- Policy provided by the Governance body provides guidance to the Science body based on program goals and objectives but does not define the actual science being conducted by the Science body.
- Likewise, the science conducted by the Science body must be focused, strategic and applied to the key management uncertainties to best inform the decision-makers in the Governance body. Research for the sake of research that does not address priority uncertainties that inform management improvements must be avoided. Therefore, the Science body needs to be strategically managed via prioritization of uncertainties, ensuring that key cause-and-effect relationships can be made and that key trend monitoring can assess performance and effectiveness.
- The Science body must include both monitoring and assessment responsibilities, as described in Section 7. Collecting monitoring data without assessment and linking the data back to management actions and priority uncertainties wastes time and resources.
- Data management and access are common challenges to effective assessment and data availability; consequently, a specific focus on data management and accessibility is critical to the Science body.

Based on these challenges, the Planning Team recommends structuring the Program Management body in a way that efficiently develops, oversees, and manages the science conducted under the Program, which can be done with a relatively small Science staff. The Planning Team recommends that Science staff do not conduct the field-based science activities; instead, qualified Native American Tribes, agencies, NGOs, academic institutions, and/or contractors should be contracted to conduct the field components of the Science program under the direction of a Science Coordinator. Analysis could be shared between Program staff and contractors, depending on the experience level of the participants. Data management should be conducted by Program staff to provide consistency, accessibility, and quality assurance/quality control (QA/QC).

Importantly, one of the first tasks that the Science body should conduct is to review, refine, and use the prioritized specific and broad restoration and conservation actions in Section 5. A second task that the Science body should complete is to refine and adopt the priority monitoring and assessment needs identified in Section 7 that will inform the understanding of the ecological responses to management actions (cause-and-effect, trend, and adaptive management), as well as research needs to fill priority information gaps needed to improve management actions. Accordingly, the Planning Team recommends inclusion of the following staff within the Science body (Figure 6-2):

- *Science Coordinator*: Responsible for developing, coordinating, and implementing science priorities for the Program. This coordination role will include coordination with scientists and technical staff within and outside the Program (e.g., Native American Tribe and agency technical staff and the SAB) and contractors / agencies / Native American Tribes hired to conduct Program Science. The Science coordinator should develop annual science work plans and budgets (with the chief financial officer), maintain and update priority information needs based on monitoring and assessment results, update conceptual models and scientific hypotheses, and develop adaptive management experiments where warranted. The Science coordinator will also likely be the technical representative for outside science contracts. Accordingly, the Science coordinator should be able to integrate across disciplines that are expected to be important for the Eel River (e.g., fisheries, ecology, water quality, fluvial geomorphology, riparian ecology).
- *Watershed Monitoring Field Leads (2)*: Responsible for field monitoring assistance and coordination with agencies, Native American Tribes, NGOs, and academic institutions to ensure quality field data collection, field method consistency, field techniques training and sharing, and field data collection coordination amongst partners. These leads would coordinate field efforts between partners and Science coordinator, sampling and data analyst, and database/GIS manager. Assumes one monitoring field lead for the upper Eel River and sub-watersheds and one monitoring field lead for the lower Eel River and sub-watersheds.
- *Sampling and Data Analyst*: Responsible for developing or advising study plans and preparing RFPs for science, monitoring, and assessment projects approved by the board of directors. These study plans should be developed cooperatively with the implementing entities (agencies, Native American Tribes, NGOs, academic institutions) and focus on ensuring that the study plan can address the priority question with a reasonable cost and time effectiveness and provide sufficient statistical power to reduce uncertainty to a desired level. The sampling and data analyst must be able to advise across the range from project-level to program-level monitoring and assessment as described in Section 7. The sampling and data analyst may conduct some modeling and analysis of data collected by others but more likely will provide guidance (if needed) to entities hired to conduct Program science. Accordingly, this sampling and data analyst should have expertise in statistical analysis, ecological modeling, field work, environmental variability across different disciplines, and science budgeting and possess the ability to convey/translate complex scientific information to decision-makers.
- *Database/GIS Manager*: Responsible for managing and sharing field and spatial data for the Program as described in Section 7.4. Responsibilities would likely include developing or advising study plans for field data and spatial data management, guiding QA/QC processes for entities collecting data, providing a user-friendly method for outside access to spatial and Program data, and facilitating public education by sharing data and analytical results.

6.1.4 Planning

The key Planning role in a large-scale restoration program is to ensure that the restoration, conservation, and monitoring activities directed by the Governance body can be implemented in a timely and lawful manner. Planning activities depend on the types of restoration, conservation, and monitoring activities being undertaken and often include administrative and financial specialists, environmental planners, engineers, realty specialists, surveyors, regulatory compliance specialists, and project managers. Cost-effective and timely restoration implementation requires good planning and the appropriate level of administrative support.

Given that the Program is likely to include a combination of monitoring, restoration, and conservation actions as described in Sections 5 and 7, the Planning Team recommends hiring staff to conduct administrative/financial duties, project planning and contracting duties, regulatory compliance, and realty/access actions (rights-of-way, conservation easements, land purchases). Accordingly, the Planning Team recommends inclusion of the following (Figure 6-2):

- *Regulatory Compliance Coordinator*: Responsible for developing regulatory compliance strategies for program-led monitoring, restoration, and conservation projects to facilitate cost-effective and timely implementation. Depending on the funding source, duties could include strategies for programmatic regulatory compliance, compliance with the California Environmental Quality Act, and permitting (either leading the effort or supporting partners conducting the compliance). The regulatory compliance coordinator would also work closely with Implementation staff and other entities to ensure that permit requirements are followed for monitoring, restoration, and conservation actions.
- *Realty and Access Coordinator*: Responsible for obtaining land and right-of-way access when conducting monitoring and restoration activities and for overseeing realty/property boundary activities associated with conservation easements and land purchases. Given the coordination role of the realty and access coordinator, this person could also assist the executive director with public questions and interactions associated with Program activities.
- *Environmental Planner*: Responsible for working closely with the Implementation body to plan and manage implementation projects and coordinating with the Science and Implementation bodies to integrate their activities (e.g., prioritized projects described in Section 5). The environmental planner would also work closely with the Implementation body and chief financial officer on budget planning and cost estimation.

6.1.5 Implementation

The key role in implementation of a large-scale restoration program is to ensure that the restoration implementation and conservation activities that are directed by the Governance body can be achieved in a timely and lawful manner. In some programs (e.g., San Joaquin River Restoration Program), restoration designs are developed by program staff or technical agency teams; in other programs (e.g., Trinity River Restoration Program and Platte River Recovery Implementation Program), program staff provide guidance on designs and contract with Native American Tribes, agencies, or NGOs to develop the final designs and bid documents. Program staff then conduct construction inspections and review as-built surveys/documentation to ensure that the project was constructed per design. Close coordination with the Science body is required to ensure that the pre-project and as-built surveys are compatible with the need of any project-level monitoring and assessment. Staffing needs for the Implementation body will depend on the role of the Program in how implementation is conducted (funding versus design versus level of involvement in implementation) and can include design engineers, cost estimators, environmental planners, realty specialists, surveyors, and project managers.

For the Program framework, Section 4 distinguishes between two general categories of actions: ecological restoration and watershed conservation. These two interrelated categories of actions involve unique program-level implementation steps and workflow with different roles and responsibilities, coordination, and integration among Program staff and participants. Key steps involved in implementing ecological restoration projects typically include planning (e.g., identifying the problem and establishing goals and objectives), project design (e.g., conducting site investigations, developing and analyzing alternatives, and creating construction-ready design plans and specifications), permitting and regulatory compliance, contracting, construction, and implementation monitoring.

Based on the restoration and conservation priorities developed in Section 5, Implementation staff would develop design guidelines and other technical products that support planning, design, implementation activities that range from watershed to site-specific scales. As part of these efforts, project phasing and synchronization activities may be identified to ensure that spatial and temporal dependencies (e.g., potential benefits to species, life stages, life-history strategies; potential sort or long-term negative impacts of a project on other locations) that Implementation staff will need to consider in the planning of restoration and conservation projects. The Planning Team envisions that two types of restoration solicitation strategies will be required, consistent with the categories described in Section 5:

- *Specific (Program-directed) Actions*: Actions that enable the Program to direct a significant portion of resources to spatially explicit critical actions and/or projects that are high priorities identified by the Program and are expected to result in the most meaningful and substantial restoration and conservation outcomes; and
- *Broad (non-Program-directed) Actions*: Actions that are more generically defined priorities in sub-basins and/or channel archetypes and that are amenable to implementation by numerous entities (Native American Tribes, agencies, NGOs, contractors) to propose, design, and implement through competitive funding programs, based on the unique objectives, priorities, expertise, and geographic influence of their individual organizations.

These two categories ensure known, high-priority projects get designed and implemented under the Program and also allow other entities to be innovative in identifying and developing projects opportunistically, assuming they are consistent with the Program's general priorities as described in Section 5.

To keep the Implementation body staffing requirements as low as possible to efficiently fulfill their responsibilities, the Planning Team recommends that the Program (1) conducts the planning and advisory role for restoration design and implementation for Program-directed projects described above and (2) rely on partner entities (contractors, Native American Tribes, NGOs) to develop the restoration designs and conduct restoration implementation. Program staff should engage in developing conceptual designs for the priority restoration projects, develop planning-level cost estimates, prepare RFPs for Program-directed implementation entities, review proposals for non-Program-directed restoration or conservation projects, then provide technical assistance (as needed) to the implementation entities to collect pre-project data, finalize and document designs, implement the project, and conduct as-built surveys and prepare documentation. This staffing approach results in the following Implementation staff that would work closely with Planning and Science staff (Figure 6-2):

- *Implementation Project Manager*: Responsible for working closely with the Science and Planning teams to ensure that the prioritized projects are pursued in a logical sequence, coordinated and integrated within the Program, and designed/implemented as intended. Working in concert with the implementation planner/estimator, the implementation project manager may work with Science and Planning staff to develop conceptual designs, develop preliminary cost estimates, develop RFPs for Program-directed projects, develop RFPs for non-Program-directed projects, develop annual budgets with the CEO, and develop strategic plans and yearly planning budgets for the Implementation staff.
- *Implementation Planner/Estimator*: Responsible for working closely with the implementation project manager to help plan and budget restoration and conservation implementation projects. The implementation planner/estimator may also serve as a technical representative for implementation contracts funded by the Program, conduct site inspections, facilitate pre-project and as-built data collection efforts, assist the implementation project manager in developing RFPs, and estimate restoration and conservation project implementation costs for budgeting and strategic planning.
- *Watershed Implementation Coordinators (2)*: Responsible for assisting agencies, Native American Tribes, and NGO partners on implementation throughout the watershed and coordinating with the Implementation project manager and Implementation planner/estimator. These coordinators would assist partners on technical issues and design consistency on watershed restoration projects. Assumes one coordinator for the upper Eel River and sub-watersheds and one coordinator for the lower Eel River and sub-watersheds.
- *Public Information Officer and Tribal Liaison*: Responsible for working with Program staff on developing and disseminating information generated by the Program to the public, agencies, and Native American Tribes. This public information officer and Tribal liaison would assist the Executive Director in preparing briefing documents, conducting interviews, preparing press releases, and coordinating with Native American Tribes in the Eel River basin.

6.1.6 External Review

An External Review body is a critical component of a well-functioning large-scale restoration program, if done strategically and efficiently. External review of the Science body (e.g., TACs or SABs) is common in large restoration programs, whereas external review is less commonly applied to the Governance body and Program Management bodies. However, because the Governance body and Program Management bodies are responsible for decision-making and implementation (rather than the Science body), it is important that external review of both the Science and decision-making/implementation functions of the Program occurs with some frequency. To facilitate transparency and trust, external review should be performed by topical experts who are familiar with the goals, objectives, strategies, and actions of the program but have no policy or financial motivations for their participation (i.e., independent).

External review of Science is best done by a TAC or SAB that is composed of independent topical experts that cover the range of applied science topics. The external SAB should be a small (approximately 5 individuals), interdisciplinary staff with extensive experience in applied science and implementation. They should be innovative problem-solvers, who are experts in their field. The role of the SAB should focus on big-picture science and implementation questions, such as advising the program with priority scientific uncertainties, conceptual models, interpretation of key research results, prioritization of restoration and conservation actions, and other higher-level Science needs. The time step for this type of advising should be on the order of yearly review so that the SAB remains at arms-length and does not become part of the Program staff. The SAB can also provide review of specific Science reports (e.g., monitoring results), but it should only review a small number of key reports, but not all the reports, so that it maintains independence from the Program. Review of Science reports by the SAB should be conducted by the entire group to avoid individual members from reviewing reports in isolation from the rest of the group.

External review of the Governance body and Program Management bodies should also be conducted, but often by a different group of topical experts whose expertise is focused on Program Management rather than strictly Science. This external review could be performed by engineers, administrators, program managers, attorneys, financial experts, and other experts. These experts may not necessarily need to be associated with ecosystem restoration programs, but they should have experience in managing and implementing large multidisciplinary programs. The time step for Governance and Program Management review should be longer than the Science review due to the lag time between management decisions, implementation, and outcomes, likely on a 3- to 5-year time step. Institutionalizing this review of Governance and Program Management is usually more difficult to achieve because the Governance body may not want to be exposed to potentially critical external review; however, given the challenges and scientific uncertainties associated with large-scale ecological restoration programs, the External Review body is extremely important to improve decision-making and Program implementation and build trust with the public.

6.2 Proposed Organizational Chart for Program Entity

Figure 6-2 synthesizes the preceding information into a potential organizational chart for a new Program that is largely based on a non-profit corporate structure similar to the Klamath River Renewal Corporation. The organizational chart lists recommended Program staff within the dashed box, and external (non-employees) outside the dashed box. The proposed organizational chart is intended to keep the staff numbers as small as possible (less than or equal to 15 full-time employees), but sufficient to accomplish the tasks needed to successfully run and implement the program. For comparison, the Klamath River Renewal Corporation has 6 employees; the actual number of employees needed for the Program will need further scoping and discussion during the next phase of Program development. As an initial estimate, assuming an average cost of $170,000 per employee for fully burdened cost (salary, benefits, taxes), annual staff costs would be approximately $2.5 million.

6.3 Potential Funding Strategies

As mentioned at the beginning of Section 6, the Program Management framework assumes that a large-scale, centralized restoration and conservation program is needed for the Eel River. This framework will require stable funding for the following reasons:

- Employing and recruiting highly qualified staff shown in Figure 6-2 (e.g., unstable or uncertain funding will discourage applicants);
- Ensuring continuity of planning, design, and implementation tasks to facilitate timely and cost-effective implementation; and
- Reducing the time and effort that Program staff and partners need to spend pursuing funding, allowing them to spend more of their time on Program implementation rather than fundraising.

Ideally, a large capital endowment (e.g., similar to the Headwaters Fund) could be obtained where interest revenue generated by the endowment would be sufficient to fund all Program administration and operational costs in perpetuity, and ideally a portion of annual restoration and conservation action implementation costs. At this point, there is no large capital endowment in place, although several potential sources are being explored. Even with an endowment, a portfolio of potential funding and in-kind support sources will likely be needed to fully implement the Program, as conceptualized in Figure 6-3. A primary role of the board of directors and executive director will be to strategize and obtain funds and in-kind support necessary to fully implement the Program and minimize interruptions to the funding stream that would delay implementation of restoration and conservation actions.

6.3.1 Potential Funding Allocation Processes

As mentioned above, the Planning Team recommends two processes for allocating restoration or conservation implementation project funding: (1) Program-directed funding for targeted projects, and (2) non-program-directed funding to enable implementation entities to identify potential high priority projects that meet broad Program goals and priority action types in sub-basins and/or channel archetypes identified by the Program.

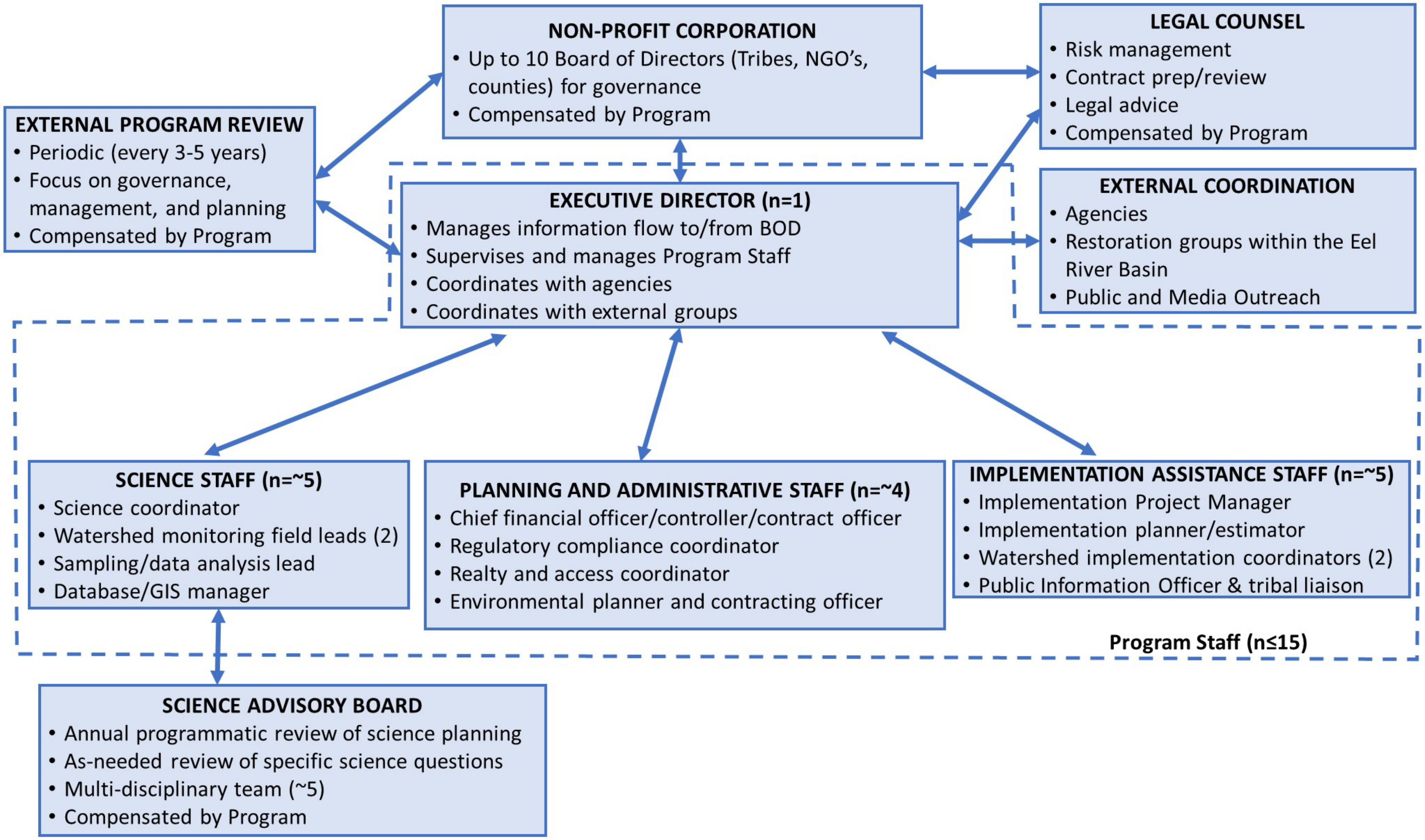


Figure 6-2. Recommended organizational structure (based on a non-profit corporate structure) for the Eel River Restoration and Conservation Program.

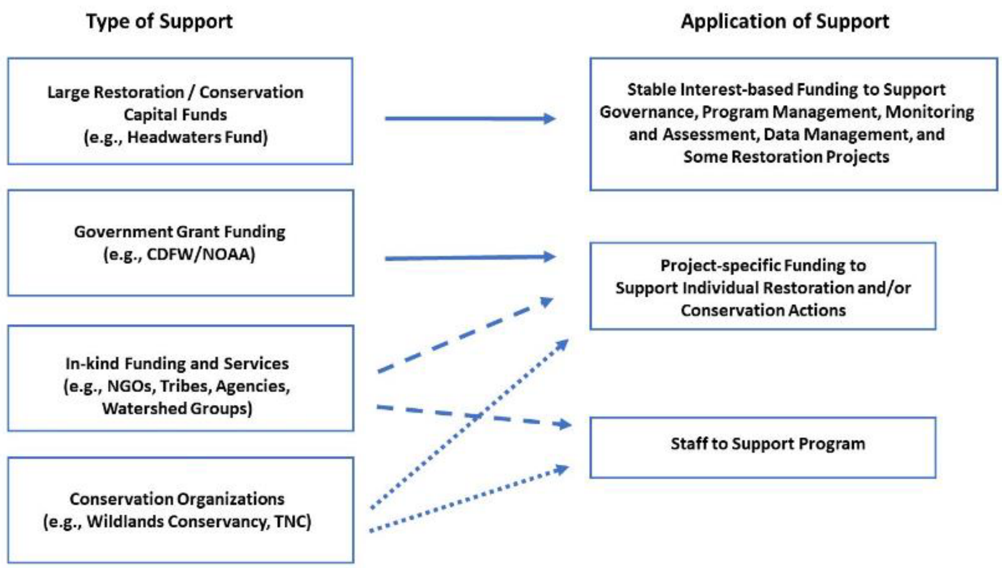


Figure 6-3. Potential funding and in-kind service support for the Eel River Restoration and Conservation Program and how that support could be used by the Program.

For Program-directed funding, the Implementation body (Figure 6-2) could develop conceptual designs for a high-priority project, a planning-level cost estimate, and an RFP for outside services to design and implement the project in either a competitive or non-competitive manner. This strategy would enable more rapid design and implementation of priority projects, and cost controls would be in place via cost estimating and close coordination by the Implementation body with potential design and implementation entities. A proportion of the total annual implementation budget could be assigned for these directed actions.

For non-program-directed funding, the Science, Planning, and Implementation bodies could prepare a general RFP to solicit proposals for restoration or conservation projects in prioritized geographic areas or channel archetypes (i.e., not site-specific), and encourage watershed groups, NGOs, Native American Tribes, and others to solicit cost proposals for planning and design for specific sites that they recommend as priority sites based on the guidelines provided by the Program in the RFP. This broader RFP process would allow local watershed groups, NGOs, Native American Tribes, and others that may have much more specific knowledge about potential restoration or conservation projects than Program staff to develop funding proposals to plan and design those projects. In other words, this funding strategy would enable innovation and creativity and inclusion by these local watershed groups, NGOs, Native American Tribes, and others in project identification, planning, design, and implementation. A proportion of the total annual implementation budget could also be assigned for these non-directed actions. Program staff would then review the proposals, rank them based on priorities and funding availability, and award funds to plan, design, and implement the project.

7 MONITORING AND ASSESSMENT FRAMEWORK

A scientific framework for monitoring is necessary to track progress toward the Program's vision and goals (Section 1.2.1), ensure that restoration actions are designed to evaluate and improve hypotheses about focal species recovery (Sections 3 and 4), and reassess the prioritization of restoration and conservation actions (Section 5) as data gaps are filled and fish demographics change through time. In addition, monitoring provides the raw information needed to inform and engage the community about the fish population recovery in the Eel River watershed, which is a key part of the Program's vision. In short, implementation (Section 6.1.5), along with monitoring and assessment (Section 7), are the core enterprises of the Program (Section 6). Achieving the Program's vision for recovery depends on robust execution of, and interaction between, these core enterprises.

The basic challenge of monitoring to guide recovery of anadromous fish populations was summarized by Reeves et al. (1991) and paraphrased by Bilby et al. (2023):

> *Habitat and fish population measurements must be collected in a manner that enables habitat changes due to restoration to be linked to demographic changes in salmon.*

To address this challenge, the monitoring and assessment framework (monitoring framework) must identify which metrics and sampling scales (spatial/temporal) are "necessary, feasible, and practical to measure" (Botkin et al. 2000). The program must also nimbly and effectively synthesize monitoring data into clear guidance for restoration practitioners and/or information for the public (Botkin et al. 2000). The monitoring framework must address how and where the program can integrate ongoing monitoring efforts within the basin, particularly fish demographics monitoring conducted by the State of California and Native American Tribes, and NGO partners, and conversely, where new monitoring will be needed to address critical information gaps and decision feedback loops. Finally, this framework must describe how the monitoring component relates to and interacts with the broader Program. This section describes the scientific framework for monitoring anadromous fish habitat and population responses to restoration and conservation actions in the Eel River watershed. While anadromous fish habitat and populations are the focus of much of the monitoring described in this section, the overarching goal of the Program is to improve the river corridor ecosystems that support these native fish populations. Conservation strategies and actions are a critical component of an overall recovery strategy and will be considered within the monitoring program at multiple spatial and temporal scales.

7.1 Goals and Objectives

The purpose of the monitoring framework is to define the overarching goals of a future Eel River monitoring program, identify the key components of the monitoring program, and describe the utility and merits of each component and how each integrates with the monitoring program as well as the broader Program.

The goals for a future Eel River monitoring program are as follows:

1. Evaluate whether restoration and conservation actions are working to meet the Program's vision and goals for native anadromous fish recovery;
2. Use key focal species populations and habitat metrics to adapt, refine, and/or reprioritize restoration and conservation actions, as needed; and
3. Share the recovery trajectory of anadromous fish in the Eel River watershed with the public in accessible ways that inform and engage the community.

The monitoring framework described in this section establishes the necessary components of a monitoring program and discusses tradeoffs between monitoring designs, but it does not dictate the specific methods, sites, and statistical designs that will make up a final monitoring plan nor does it provide specific details about operating such a monitoring program (e.g., equipment, staffing). The monitoring plan will be developed during Phase 2 and implemented during Phase 3.

This monitoring framework focuses on monitoring and assessment and identifies opportunities for conducting adaptive management when and where it makes sense (Section 7.5). Adaptive management is a structured approach to decision-making that uses new information as it becomes available to inform and adjust hypotheses and approaches to achieving restoration and conservation goals and objectives. This structured process is intended to reduce scientific uncertainty in evaluating the effectiveness of restoration and/or conservation actions over time. This monitoring framework also describes other feedback loops such as focused iterative hypothesis testing (hypothetico-deductive approach) and less formal collaborations with program partners that are intended to generate knowledge, inform performance and the potential need to adjust restoration and conservation actions, and increase the pace of fish population recovery.

The following five key components/concepts have been identified to describe the recommended structure and integral processes of the monitoring framework:

1. Monitoring program oversight and coordination among partners (Section 7.2)
2. Monitoring and assessment process (Section 7.3)
3. Data management structure (Section 7.4)
4. Adaptive management structure (Section 7.5)
5. Program linkages (Section 7.6)

Descriptions of these five key components/concepts are presented in the following subsections (Sections 7.2–7.6) and provide the scientific basis and supporting rationale for an effective monitoring program. They also comprise the primary objectives required to achieve the stated goals of the monitoring program. Section 7 concludes with a discussion of additional considerations regarding the monitoring framework and the necessary steps required to develop a monitoring plan during Phase 2 (Section 7.7).

7.2 Monitoring Program Oversight and Coordination among Partners

Due to the large size of the Eel River watershed and the numerous entities currently involved in conducting monitoring in the basin, the Planning Team anticipates that the monitoring program will be most effective if Program staff serve in an oversight role to coordinate and guide monitoring rather than being the primary conductors of monitoring activities. Most of the field monitoring is expected to be performed by Program partners (e.g., state agencies, Native American Tribes, contractors, and NGOs) with analysis and assessment shared between partners and Program staff, this will provide the greatest benefit and effectiveness for assessing the extent to which the monitoring program objectives are being met.

Key elements of the monitoring program's role include the following:

- Developing the monitoring plan and collaborating with Program partners to organize the yearly implementation of monitoring tasks;
- Managing, synthesizing, and sharing data;
- Providing a forum for practitioners to discuss monitoring strategies, methods, and results and any lessons-learned to inform future monitoring; and,
- Assessing whether monitoring program goals are being achieved.

To be most effective, the monitoring program needs to coordinate closely with Program partners to provide input on monitoring strategies and methods, allow information exchange between the monitoring program and partners, and acquire and use monitoring data for the assessment process.

Monitoring oversight by Program staff should include the following:

- Establishing a structure and staffing that allows for assessment to ensure monitoring is achieving Program goals;
- Prioritizing and coordinating monitoring activities, locations, and methods;
- Conducting specific monitoring activities that fill data gaps and answer specific questions; and
- Where appropriate, developing and implementing adaptive management experiments.

7.3 Monitoring and Assessment Processes

Monitoring and assessment are fundamental to determining whether, and to what extent, restoration and conservation actions are having the intended effect on improving habitat conditions for focal fish species and, more broadly, whether program implementation is achieving species recovery objectives. To meet these goals, a range of monitoring types and scales are necessary. A key concept used to organize the different types and scales of monitoring within the monitoring framework is differentiating between **program-level** monitoring and **project-level** monitoring. Program-level monitoring focuses on whether the program is on a trajectory toward achieving its goals over a large spatial and/or temporal scale (e.g., anadromous fish population recovery), while project-level monitoring focuses on whether restoration and or conservation actions are achieving their project-specific intended effect (e.g., increasing quantity of juvenile rearing habitat at a site).

There is frequent reference to various spatial scales in Section 7, with the generally hierarchical structure from large to small as follows: watershed (i.e., Eel River watershed [9,538 km^2]), sub-watershed (i.e., the seven primary sub-watersheds [~1,500 km^2 (range 136–2,072 km^2)]), sub-basin (e.g., the 113 HUC-12 sub-basins [~100 km^2 or less], reach (or segment) ~100s of meters, habitat (or site) ~10s of meters]). Additional discussion of spatial scales is provided in Section 2.1.

In their simplest form, program-level monitoring and project-level monitoring may be discrete categories; however, within this monitoring framework, these concepts are on a continuum of spatial and temporal scales with different levels of inference (Figure 7-1). Program-level monitoring is generally conducted over larger spatial scales and over longer temporal scales compared with project-level monitoring. These differences in scale determine which methods are most appropriate for program- and project-level monitoring and assessment.

Both program-level and project-level monitoring will be designed to evaluate the success of prioritized restoration and conservation actions. The process for implementing both program- and project-level monitoring involves similar steps—but differs in the spatial scale, design, timeline, and scope of inference (Figure 7-1). The monitoring and assessment steps for both categories follow:

- Defining the specific objectives for each monitoring effort;
- Identifying hypotheses to be tested;
- Developing a monitoring design, including metrics to be measured, replications, and sampling methodology;
- Developing a data collection and data management workflow;
- Performing implementation monitoring;
- Preforming assessment of monitoring data; and
- Performing knowledge integration, synthesis, and sharing to improve implementation effectiveness (e.g., increase ecological response, decrease effort/cost and time) inform (1) restoration implementation and (2) the public and managers about the trajectory of recovery toward the program's ultimate objectives.

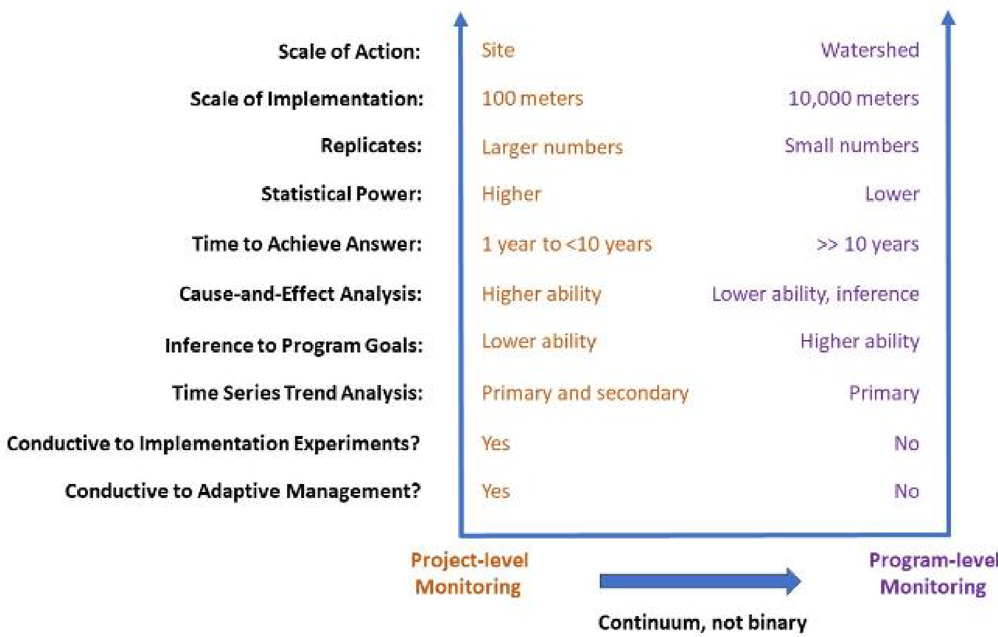


Figure 7-1. Conceptual framework for project-level monitoring and program-level monitoring.

While many of the monitoring materials and concepts described or referenced in this section are based on, or were developed for, anadromous salmonids, the monitoring strategies and approaches can be applied to other fish species including Green Sturgeon and Pacific Lamprey (focal species). In addition, while the Program and Plan emphasize native fish, the Program goals are largely ecosystem-based and include restoring physical habitat conditions and properly functioning ecological processes that support the recovery of healthy riverine ecosystems throughout the Eel River watershed. Program- and project-level monitoring and assessment are described in more detail in Sections 7.3.1 and 7.3.2, respectively.

7.3.1 Program-level Monitoring and Assessment

Following from the general description of program-level monitoring and assessment in Section 7.3, this section provides additional information and detail regarding the potential scope and scale of program-level monitoring and assessment within the broader Eel Restoration and Conservation Program (Figure 7-2). Program-level monitoring and assessment is intended to:

- Establish status and trend population data for focal fish species and life histories (Section 3) and evaluate the overall success of the Program at restoring native anadromous fish populations and ecological functions in the Eel River watershed;
- Identify and fill key data gaps that would inform refinements to restoration site planning and prioritization (Sections 4 and 5), and improve implementation processes and approaches once the program has begun; and,
- Evaluate and refine the hypotheses about the cause-and-effect relationships between restoration actions and ecological response using an experimental approach to restoration implementation (see Section 5.2.2). Iterative hypothesis testing, through monitoring of implementation projects, and communication between Science staff and Implementation staff, can generate institutional knowledge to increase the pace of recovery.

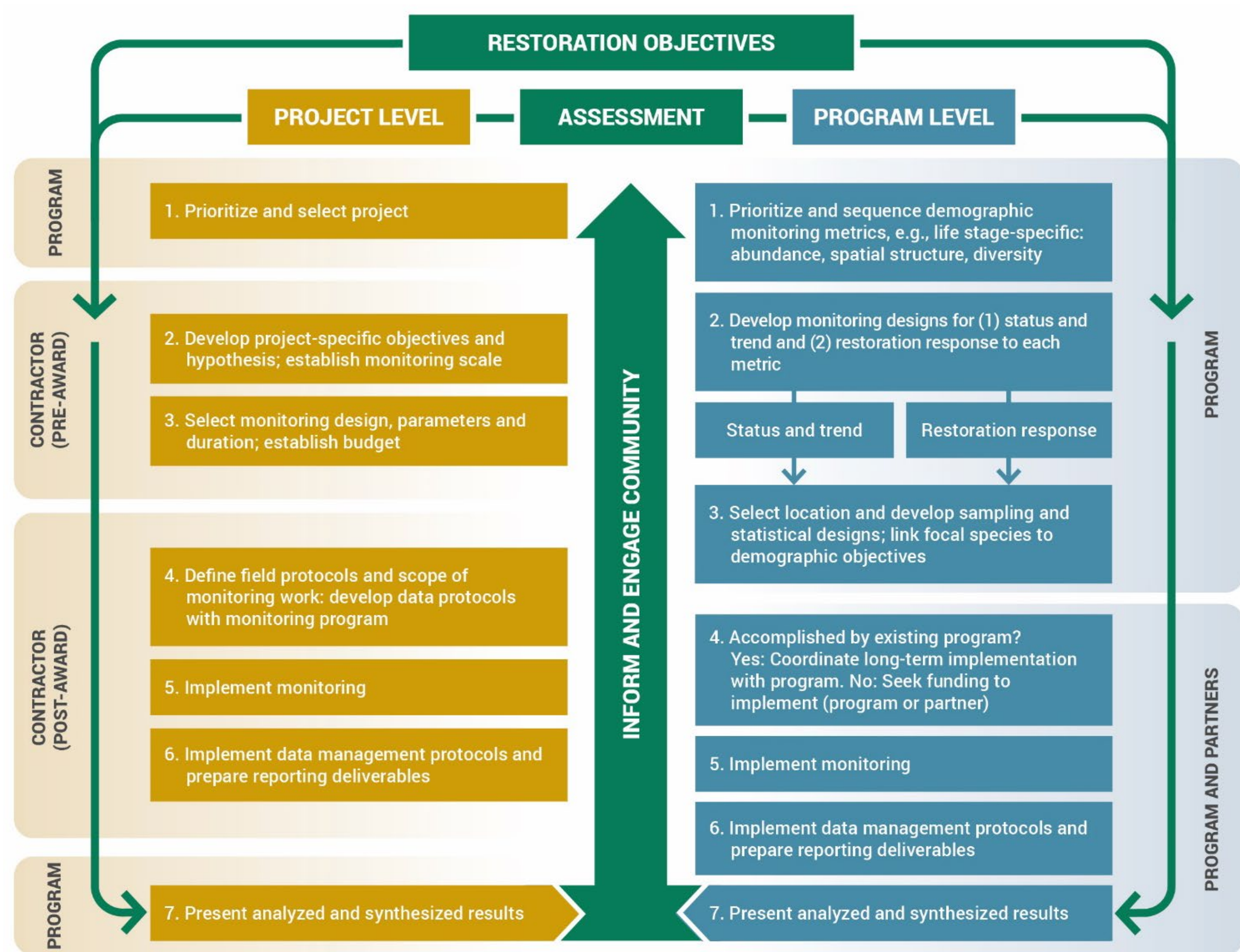


Figure 7-2. Basic process for project-level (left) and program-level (right) monitoring and assessment.

7.3.1.1 Monitoring Types

Program-level monitoring focuses on three primary types of monitoring—status, trend, and validation—and is intended to assess changes in demographic rates of the focal population, often over large spatial scales (e.g., the seven primary sub-watersheds).

- *Status and Trend Monitoring*: These types of monitoring can be applied to physical habitat, water quality, or fish population metrics to characterize the current conditions (status) and change through time (trend) of key habitat or population metrics. For fish, the metrics used (Table 7-1) and the spatial and temporal sampling regime will be designed to evaluate the recovery trajectory of the existing fish populations, as well as the occurrence of rare or imperiled sub-populations and life histories that were historically important but may not be commonly expressed in the current population.
- *Validation Monitoring*: This type of monitoring evaluates whether hypothesized cause-and-effect relationship between restoration and/or conservation action and response variables are realized.

At the program level, status and trend monitoring will focus on population abundance and life-history diversity of focal fish species and include metrics guided by the species conceptual models (Section 3) and agency recovery goals such as NMFS's viable salmonid populations criteria (i.e., abundance, productivity, spatial structure/distribution, and diversity) (McElaney et al. 2000).

When possible, validation monitoring will be conducted in a "hypothetico-deductive" framework (Starfield and Bleloch 1986), where the monitoring program (1) starts with hypotheses (Sections 3.3.2 and 5.2.2); (2) constructs simple quantitative or conceptual models that make directional predictions about how the system will respond to restoration; and (3) develops monitoring designs to perform quick iteration between models (hypotheses), data tests (implementation and monitoring), and revised models to build knowledge. This approach would use restoration implementation efforts as experimental designs and knowledge integration would depend on assessment (Section 7.3.3)

Table 7-1. Common metrics used to evaluate anadromous fish population health within status, trend, and validation monitoring.

Population metrics	Methods	Spatial scale[1]	Temporal scale	Priority[2]
Marine survival	LCM, Floy tags,[3] coded wire tags, smolt-to-adult ratios	Sub-watershed or sub-basin	Long term (4+ years)	3
Adult abundance	Sonar, LCM/IMW, weirs, creel and spawner surveys	Watershed, sub-watershed, sub-basin	Multiple time scales	2
Redd numbers	Spawner survey, drone video	Reach	Seasonal or event based	3
Egg-to-fry survival	Emergence traps, substrate bulk samples, permeability	Reach	Event based (weeks)	4
Juvenile or larval abundance	Snorkel survey, electrofishing, video	Habitat or reach	Season-specific	3
Juvenile density	Snorkel survey, electro fishing, seining	Habitat or reach	Daily	3
Juvenile survival (over-summer; over-winter)	Mark-Recapture	Habitat or reach	Season-specific	3
Juvenile growth	Mark-Recapture, length distribution analyses	Habitat or reach	Season-specific	3
Juvenile residence time	Mark-Recapture	Sub-basin	Season-specific	4
Smolt production	Downstream migrant trapping, video	Watershed, sub-watershed, or sub-basin	Season-specific	2
Smolt migration survival	Acoustic telemetry, radio telemetry, PIT tagging	Sub-watershed or sub-basin	Monthly	2
Population spatial structure	Snorkel survey spatial design, spawning survey, sonar, telemetry	Sub-watershed or sub-basin	Annual	1
Life-history diversity	Combination of methods: Presence/absence (eDNA), isotope studies, mark-recapture, snorkeling, trapping, genetic analyses, modeling.	Sub-basin	Multiple time scales, more valuable in the long term	3

Notes: IMW = intensively monitoring watershed
LCM = life-cycle monitoring
eDNA = environmental DNA
PIT = passive integrated transponder

1 Spatial scales from large to small include: watershed, sub-watershed, sub-basin, reach (or segment), and habitat (or site). Spatial scales are described in more detail in Section 2.1.
2 Relative priority from 1 (higher) to 4 (lower).
3 External tags that are long, narrow, colored and coded. Also known as spaghetti tag. Typically inserted just underneath the dorsal fin.

7.3.1.2 Program-level Monitoring Design and Metrics

As discussed elsewhere, most of the descriptions and examples included in Section 7.3 pertain to anadromous fish populations, however, other important response variables such as sediment, water temperature, and stream flow will be considered for both program-level and project level monitoring.

Common metrics to evaluate the health of an anadromous fish populations and to be used in status, trend, and validation monitoring are shown in Table 7-1. A critical decision point in program-level monitoring is the spatial scale at which population monitoring takes place. In large watersheds across the Pacific Northwest, anadromous fish make use of almost the entire stream network (including small headwater streams to off-channel estuarine habitats) through complex and co-occurring life histories (e.g., Hilborn et al. 2003). This characteristic of anadromous fish, which provides resilience to their populations (e.g., Moore et al. 2014), also makes monitoring those populations inherently difficult. Thus, a fundamental tradeoff in population monitoring is between spatial (and population) scale and the resolution of monitoring data. Two program-level scales are as follows:

- *Watershed and Sub-watershed Scales*: At larger spatial scales (e.g., the size of the Eel River watershed [9,538 km^2] or the seven primary sub-watersheds [~1,500 km^2]), fish monitoring tends to focus on adult escapement (fish in) and smolt production (fish out), an approach used in the Washington State (Lando et al. 2013). Conducting this monitoring and assessment at large spatial scales provides long-term adult and juvenile fish population data, often for multiple subpopulations—an integrated view of the trajectory of population recovery. However, monitoring over these large spatial scales requires large investments in labor, materials, and time—especially to ensure an adequate recapture rate to estimate juvenile population abundance. In addition, monitoring at large spatial scales makes it difficult to draw inference between population data and restoration actions or to evaluate the recovery of fish life-history diversity (e.g., Section 1.2.1 and 3.2.3).
- *HUC-12 Subbasin or Smaller Scale*: At smaller spatial scales (e.g., the size of the 113 HUC-12 sub-basins [~100 km^2 or less]) monitoring can focus on understanding more complex relationships and employ higher-resolution sampling methods (also see Section 2 for a description of scales). The HUC-12 subbasin and smaller scales category includes the intensively monitored watershed (IMW) and life-cycle monitoring (LCM) station scale approaches to monitoring and assessment. In response to issues of scale, IMWs and LCM stations are often employed to track salmon demographic rates and determine fish and habitat responses to restoration actions (Table 7-1, Zimmerman et al. 2012, Adams et al. 2011). A basic premise of IMWs and LCMs is that complex relationships, which control a salmonid population's response to habitat conditions, can best be understood by conducting higher-resolution monitoring at smaller sub-basin scales. In an IMW or LCM, data can be collected on each life stage of focal species and related to habitat and environmental variables. An IMW differs from an LCM in that an IMW specifically includes experimental manipulation. While both IMWs and LCMs are relatively labor intensive and expensive to implement, they can provide a higher degree of confidence in estimating local demographic rates and in the relationships between habitat restoration and population response than coarser, large-scale population monitoring (i.e., they have stronger ability to detect cause-and-effect relationships). However, it is challenging to make strong inference between data collected at the IMW/LCM scale and the status and trends of the broader (e.g., watershed scale) population. In addition, depending on their size and location, IMWs and LCMs may miss key parts of the salmon life history (e.g., juvenile mainstem emigration, estuarine residence, and adult immigration. Juvenile mainstem emigration, estuarine residence, and adult immigration).

A basic, non-exhaustive, introduction to common types of program-level monitoring, their objectives, common methodologies, and their application at the sub-watershed or smaller sub-basin scale (e.g., IMW/LCM) is presented below.

Fish in–Fish out Monitoring

- *Purpose*: Adult escapement or fish in (the total number of adult fish and early maturing males or "jacks" returning to a stream to spawn) and smolt production or fish out (the total number of smolts and pre-smolts emigrating from a stream toward the ocean) are perhaps the two most fundamental metrics of the health of an anadromous fishery (Zimmerman et al. 2012, Adams et al. 2011). Adult escapement is the basis of federal listing (and delisting criteria) and smolt production represents the success (or lack thereof) of the freshwater phase of anadromous fishes life cycle.
- *Methods:* Adult escapement can be estimated using fish counting weirs, mark recapture methods, hydro-acoustic methods (DIDSON and ARIS cameras), video, and redd counts. Smolt production can be estimated using downstream migrant traps (e.g., using fyke traps, rotary screw traps, and/or incline plane traps), weirs, video, and mark-recapture methods using passive integrated transponder (PIT) tags or acoustic tags. All these approaches require statistical models to estimate total counts and abundance (Adams et al. 2011).
- *Sampling Strategies*: Fish in–fish out monitoring would ideally be conducted at locations that (1) represent the trajectories of focal populations within the Eel River (Section 3); (2) represent the diversity of key channel archetypes (Section 2.2); and (3) reflect changes from restoration investment. Accomplishing all three of these objectives with a single monitoring location is not feasible; and thus, the cost and effort associated with fish in–fish out monitoring will necessitate difficult choices.
    - Sub-watershed scale: It would be ideal to monitor these demographic rates for the focal species in each of the Eel River's seven primary sub-watersheds (Figure 2-1). If funding is limited, priority should be given to a paired watershed analysis, where the least impaired sub-watershed serves as a reference state (e.g., the South Fork Eel sub-watershed) and a sub-watershed that will receive major restoration alterations (e.g., dam removal in the Upper Main Eel sub-watershed) serves as an "impact" site.
    - HUC-12 subbasin and smaller scale: A suite of smaller, intensively monitored watersheds could serve as an "indicator" of the status and trends of fish in–fish out demographics in the Eel River. Installing IMWs across a range of key channel archetypes (Section 2.2), would allow researcher and managers to understand the relative recovery of different sub-populations and life histories and make better inference of recovery of the whole Eel River population.

Life Stage–specific Survival

- *Purpose*: Survival of anadromous fish at each life stage varies between years with environmental conditions and ecological interactions. Human alteration of a watershed often imposes survival bottlenecks that might not be apparent from fish in–fish out monitoring but can be identified with a life stage–specific survival analysis. Quantitatively linking habitat change to life stage–specific parameters in a life-cycle model (Figure 7-3) greatly benefits the process of prioritizing restoration actions "by examining the extent to which each action potentially contributes to the biological response of populations" (Jorgenson et al. 2021). This is a key step in several prioritization frameworks (e.g., the HARP model, Jorgenson et al. 2021).

- *Methods*: Accurate estimates of egg-to-fry survival and fry-to-smolt survival (Figure 7-3) are challenging to determine in the field. Emergent-fry traps, capsules, and incubation-emergence boxes are used to estimate egg-to-fry survival (NOAA 2022); however, statistical approaches and literature values are often used in practice. Substrate size composition can be used as an indirect measure of egg-to-fry survival (Tappel and Bjornn 1983). Fry-to-smolt survival, including over-summering and over-wintering survival, can be evaluated using mark-recapture techniques, with numerous marking techniques available based on fish size (Zimmerman et al. 2012). Recent advances in acoustic and radio telemetry have greatly improved estimates of smolt survival during migration (Peterson et al. 2021). Smolt outmigrant survival can also be estimated using PIT tags and mark-recapture methods using antennas and/or downstream migrant traps such rotatory screw traps or weirs (Volkhardt et al. 2007). Adult marine survival can be estimated using coded wire tags or Floy tags (Jefferts et al. 1963, Drenner et al. 2012). Adult abundance estimates, determined with sonar or weirs, can be used along with out-migrating smolt abundance to estimate smolt-to-adult return.
- *Sampling Strategies*:
    - Sub-watershed Scale: Acoustic telemetry in mainstem rivers and estuaries can provide critical information on the degree and locations of juvenile mortality and smolt during migration and estuarine residence (Peterson et al. 2021). In addition, studies on adult-holding habitat and adult survival during freshwater migration are best conducted at larger spatial scales (e.g., mainstem corridor).
    - HUC-12 Subbasin and Smaller Scale: Most other aspects of life stage–specific survival and life-cycle monitoring are best analyzed in intensively monitored watersheds or at a life cycle–monitoring station where the researchers can make spatially explicit estimates of survival parameters. A paired watershed design for intensively monitored watershed monitoring is also desirable for evaluating the effect of restoration actions on life stage-specific survival parameters (Zimmerman et al. 2012).

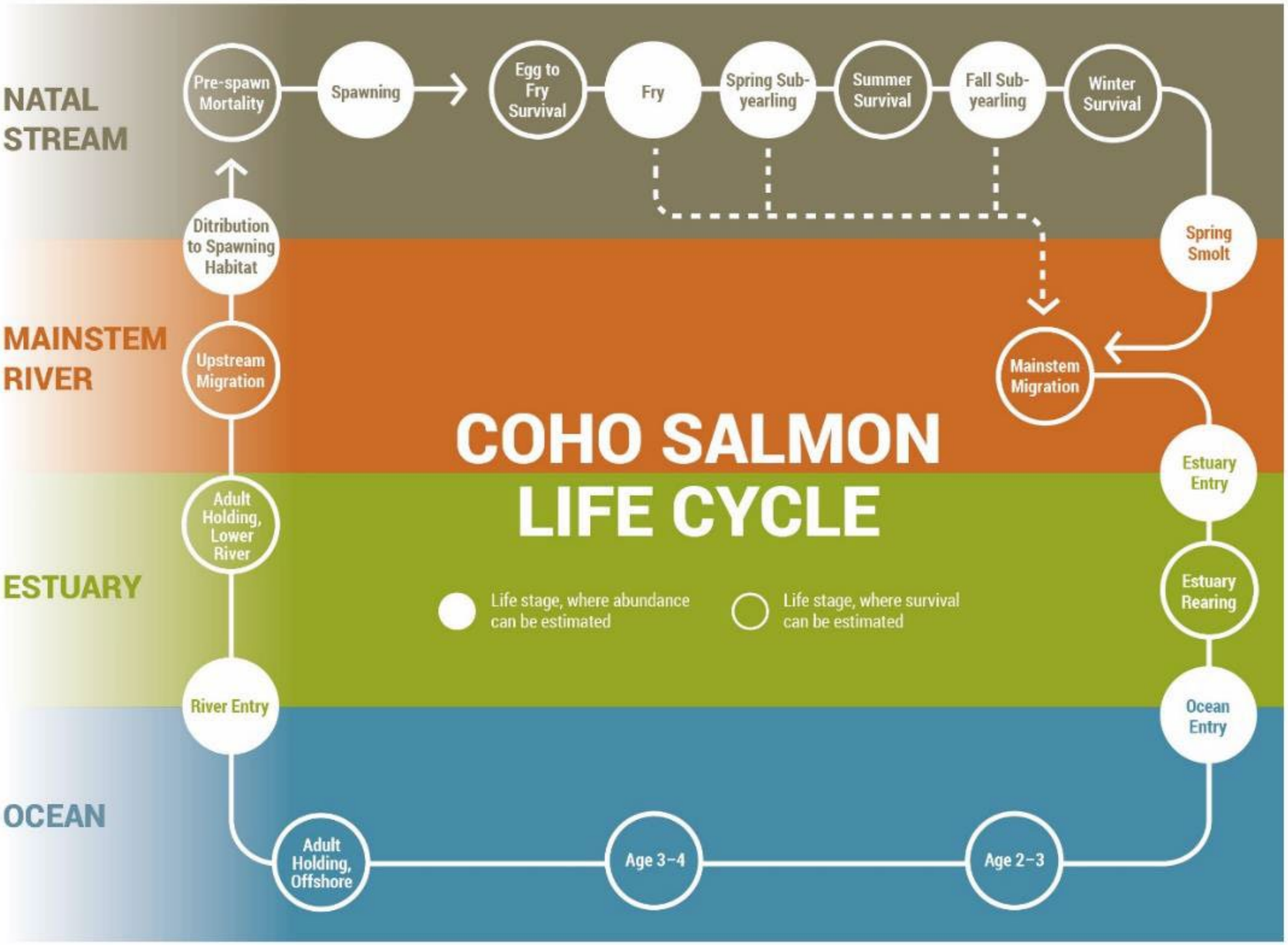


Figure 7-3. Example of a life stage–specific survival model for Coho Salmon. This type of life cycle model is useful for identifying potentially limiting life stages and estimating life stage-specific production, which can assist with identifying where restoration should be focused and/or key data gaps filled.

Population Spatial Structure and Life-history Diversity

- *Purpose*: The geographic and ecological distribution of anadromous fish across the riverscape and the connectivity between populations of fish are important traits that "protect against the effects of catastrophic events and buffer extinction risk, particularly at low abundance" (Adams et al. 2011). In addition, this Plan makes hypotheses about the relationship between salmonid spatial structure, channel archetype, and life-history diversity (Section 2.3). Spatial structure is a key metric in NMFS's viable salmonid population concept (McElhany et al. 2000). Spatial structure sampling helps to both understand where key fish population distributions extend and evaluate the diversity of anadromous fish life histories (Section 3.2.2). This Plan emphasizes the different ways that animals move within watersheds to exploit patterns of growth potential and rearing capacity through time.
- *Methods*: Spatial structure is typically evaluated primarily using summer and fall juvenile salmonid snorkel surveys in reaches selected in a random, spatially balanced manner (Adams et al. 2011). Life-history diversity can also be evaluated using movement studies (telemetry), isoscape, and genetic analyses. Telemetry studies can be used to evaluate reach-specific survival of migrating juvenile salmonids. Isoscape analysis using strontium (e.g., Sturrock et al. 2015) or fatty acid profiles (e.g., Pilecky et al. 2022) can be used to reconstruct juvenile life histories and age at habitat transitions.
- Sampling Strategies:
  - Sub-watershed Scale: Spatial structure sampling is scalable; however, it is most applicable at the scale of the projected (or hypothesized) range of focal populations. In the Eel River, these are typically larger scales (e.g., sub-watershed or larger, see Section 3.2). Population-level spatial structure is a function of habitat variability and the movement of individuals across habitats. Surveying the larger spatial areas can be accomplished using a stratified sampling method. For example, a Generalized Random Tessellation Stratified sampling technique is often used to select sites that are then allocated into panels that receive rotating effort over the years (Adams et al. 2011).
  - HUC-12 Subbasin and Smaller Scale: At smaller scales, "within population" spatial structure is also informative and can provide higher resolution information on the factors that contribute to change in spatial structure. Similar methods are applied to "population level" spatial structure; however, higher resolution sampling is conducted (including higher temporal resolution) and more covariates can be explored.

7.3.2 Project-level Monitoring and Assessment

This section provides additional information and detail regarding the potential scope and scale of project-level monitoring and assessment within the Program. Most project-level monitoring is expected to be conducted by restoration practitioners or contractors, although monitoring program resources and monitoring program staff may assist and guide project-level monitoring (Section 6.1.3 and 6.1.5). Project-level monitoring data should be stored by the Program monitoring body and/or granting agency, and the program should have a database to store and maintain monitoring and other data (Section 6.1.3 and 7.4).

Project-level monitoring and assessment are intended to:

- Guide evaluation of the success of individual restoration and conservation projects in achieving their objectives.
- Evaluate and refine the hypotheses about the cause-and-effect relationships between restoration actions and ecological response.
    - Institutional knowledge can be generated through project-level monitoring and communication between program monitoring staff and restoration practitioners can increase the pace of recovery.
    - Where possible, an experimental approach to restoration implementation should be applied using iterative hypothesis testing approach or adaptive management.

7.3.2.1 Monitoring types

Project-level monitoring generally focuses on two types of monitoring—baseline and effectiveness—and is intended to assess changes over relatively small spatial scales (typically the segment [reach] or site scale).

- *Baseline monitoring* characterizes physical, chemical, and/or biological conditions existing prior to implementation of a restoration or conservation action and provides a basis for planning and future comparisons.
- *Effectiveness monitoring* determines whether restoration and/or conservation actions have the desired effect on physical, chemical, and/or biological conditions.

Both baseline and effectiveness monitoring would be evaluated on the primary restoration and conservation action types described in Section 4: instream habitat restoration (physical habitat); off-channel habitat restoration and connectivity; estuarine restoration; riparian habitat restoration; fish passage improvement; stream flow protection and enhancement; water quality; and species management. However, the metrics and statistical design of monitoring will vary depending on site setting, restoration action, and hypothesis to be tested.

7.3.2.2 Project-level monitoring design and metrics

Each restoration action (Section 4) to be implemented and monitored will be based on a specific objective that is geared toward achieving the broader Program's watershed recovery goals (Section 1). To determine the effectiveness of the restoration action, metrics that can indicate a project's success must be selected, and these metrics must be measured with adequate temporal and spatial distribution to statistically evaluate the project's effectives. Table 7-2 provides a family of metrics that are associated with specific stream restoration project types and broadly grouped into the restoration actions described in Section 4.

Monitoring design for project-level monitoring will vary depending on the project objectives, scale, and hypotheses to be tested. The monitoring design should select the best metrics (e.g., Table 7-2), and a sampling design should have adequate spatial and temporal replication so that it is possible to evaluate the hypotheses that are being tested. In addition, monitoring needs should also include effectiveness monitoring to assess whether the project is achieving its objectives. A comprehensive discussion of sampling design for project-level monitoring is described in Roni et al. (2013). An example of this process is provided in Table 7-3.

Table 7-2. Project-level monitoring actions and potential metrics to assess.

Restoration Action Groups (from Section 4.4)	Project-Level Action Types	Potential Metrics to Assess
Riparian restoration	Active and passive revegetation	Seedling recruitment, plant survival (years), canopy cover, riparian composition, riparian plant health, and invasive plants
Instream habitat restoration	Fluvial geomorphology	Pool and riffle frequency, sinuosity, channel geometry, active channel width, bankfull width, and residual pool depths
	Longitudinal connectivity	Thalweg profiles, longitudinal depth profiles, and riffle crest thalweg depths
	Instream habitat quantity and quality—physical	Channel geometry and habitat composition (pools, riffles, and runs), large wood abundance, cover, substrate embeddedness, composition, grain size, grain size diversity, percent fines in spawning habitat, and Fredle index
	Instream habitat quantity and quality—biological	Habitat area (species-specific), species presence, abundance, behavior, residence time, growth, and survival
	Primary and/or secondary production	Primary: light penetration index, direct measurement of benthic gross primary production, and stream metabolism modeling. Secondary: invertebrate drift, benthic productions, infall, taxa diversity, and seasonal timing
Streamflow protection and enhancement	Instream flow	Degree of surface flow alteration, risk assessment, days of disconnectivity, fish passage, hydraulic thresholds, bioenergetic assessment, frequency of bench floodplain inundation, seasonal changes in flow magnitude (e.g., summer baseflow), water quality
	Groundwater	Degree of alteration to background dynamic shallow groundwater storage, alteration to infiltration capacity, and groundwater pollution
Invasive species management	Active removal/suppression of Sacramento Pikeminnow	Pikeminnow density, age-structure, and spatial distribution Juvenile salmonid densities and survival
Water quality	All types	Seasonal changes in dissolved oxygen, water temperature, total dissolved solids, turbidity, conductivity, pH, nitrogen, and phosphorous
Off-channel habitat restoration	Floodplain connectivity	Residual pool elevation, bankfull elevation, inundation flow recurrence, proportion of inundation per discharge, flood prone width, and assessment of flood control structures (levees, dykes, and tide gates)
	Secondary channels	Number, length, and habitat quality/quantity of secondary channels in geomorphically appropriate reaches
	Floodplain habitat quality	Side channel complexity, canopy density, structural diversity, buffer width, woody debris, emergent vegetation, and sediment and soil composition and distribution Biological indicators: presence/abundance/habitat quality for invertebrates, amphibians, birds, and fish

Restoration Action Groups (from Section 4.4)	Project-Level Action Types	Potential Metrics to Assess
Estuarine restoration	Saltmarsh restoration	Hydraulic: connectivity, well water depth, pore water salinity, and sedimentation Vegetation: biomass, density, composition, and macrobenthic density Organismal: fish utilization and invertebrate density and assemblage
	Ecotone	Area or volume of isotonic water under different flow conditions + see *Organismal* for saltmarsh above
	Estuarine connectivity	Degree of tidal inundation on landscape

Table 7-3. Example for project-level monitoring design and replication selection process using the impact of elevated fine sediment on egg-to-fry survival. The example steps through the process of developing a monitoring design for a specific impact.

Step in Process	Description of Monitoring Step
Identify Impact	Increased fine sediment loads due to road construction and other watershed disturbance decreases egg-to-fry survival.
Implement Restoration Action	A contractor is hired to construct bioswales below logging roads and disturbed areas at prioritized locations within a HUC-12 sub-basin. Lead-off ditches were also constructed, and riparian planting was conducted to trap sediment and minimize discharge into the stream channel.
Identify Monitoring Objective	Determine the degree to which the implemented actions reduce fine sediment deposition in the target reach during critical salmonid spawning and egg incubation periods. Estimate whether reductions were sufficient to protect egg incubation and reduce the effect of fine sediment on egg-to-fry mortality.
Develop Monitoring Hypotheses	This bioswale and riparian re-vegetation scheme are an effective method to reduce fine sediment entrainment during critical salmonid spawning and egg incubation periods.
Identify Parameters to be Measured	Percent of fine sediment (<2 millimeter) in each sample, Fredle index, embeddedness.
Develop Sampling Design	Before-after-control-impact (BACI) study design was selected, where both a control and treatment (impact) are monitored before and after restoration (Underwood 1991).
Conduct Temporal and Spatial Replication	Ideally, a power analysis will be used to determine the number of replicates. In the absence of data for a power analysis, as many replicates as possible will be obtained during each sampling event (e.g., before *x* control, after *x* control, before *x* impact, after *x* impact).
Develop Sampling Methodology	Gravel samples will be taken with a McNeil sampler at index sites and selected salmon redds to determine the Fredle index and percent fines <2 millimeter. Samples will be taken in a control reach (control), with limited fine sediment impairment, and in the project reach (impact), during the season before construction (before) and for two seasons after construction (after).

7.3.3 Assessment Strategies

A monitoring program will be ineffective if assessment of the monitoring data is not conducted. Assessment strategies discussed here address both program-level and project-level monitoring. Assessment is the process of evaluating the collected monitoring data to (1) evaluate whether restoration and conservation actions are working to meet the Program's vision and goals for native anadromous fish recovery; (2) use key focal species populations and habitat metrics to adapt, refine, and/or reprioritize restoration and conservation actions, as needed; and (3) share the recovery trajectory of anadromous fish in the Eel River watershed with the public (Section 7.1). Assessment includes hypothesis testing, data visualization, and/or narrative interpretation. A critical element of assessment is ensuring communication between Program monitoring staff and restoration implementation practitioners to ensure that data being collected to evaluate restoration actions are also used to adapt, refine, or reprioritize restoration actions. Finally, assessment also includes formal reporting on the Program's progress toward recovery goals.

7.3.3.1 Hypothesis testing

Testing to evaluate restoration hypothesis and outcomes involves both quantitative (statistical, graphical) and qualitative (logical, hypothesis-generating) analyses. Quantitative hypotheses testing depends on the sampling design, the distribution of the monitoring data, and the degree of spatial and temporal replication. For project-level assessment, projects without temporal replication and where the data are well described by a bell-shaped (normal) distribution, simple statistical analyses such as t-tests, analysis of variance (ANOVA), or correlation analyses may be adequate to statistically evaluate project-level hypotheses (Roni et al. 2013). For more complex designs with replication in time and space, linear mixed effects models, ANOVA and Akaike information criterion analyses are more appropriate. For program-level assessment, time series data, trend analyses, and indices of life-history diversity can reveal whether the focal fish populations are heading toward or away from the overall Program goals.

Qualitative hypothesis testing seeks to understand, explore, or describe the outcome of the project, develop logical and narrative descriptions of what was learned, and translate those into new hypotheses that iteratively move toward more effective restoration implementation. Qualitative assessment is particularly useful for the hypothetico-deductive approach and for communication between monitoring staff and implementation staff.

7.3.3.2 Data visualization and narrative interpretation

Data visualization allows monitoring program staff to share complex monitoring information in simple ways that communicate with decision-makers and support public outreach. Data visualization includes charts, graphs, pictures, videos and maps. Dynamic web-based visualization tools, such as ArcGIS StoryMaps,[5] can combine data visualization with spatial tools and storytelling to effectively communicate the status and trends of restoration implementation and monitoring data. Well-established and effective salmonid monitoring programs, such as the State of Alaska Salmon and People Project[6] and Salmon Status in Washington[7] rely heavily on dynamic web-based data visualization platforms to communicate the status and trends of focal species and populations.

7.3.3.3 Communication between monitoring and implementation

Monitoring and assessment are inseparable from restoration implementation in this framework, and the feedback loop is vital to the success of the Program (Section 7). Monitoring is designed specifically to evaluate the effectiveness of restoration implementation both at a project-level (Section 7.3.2) and program-level (Section 7.3.1). In turn, restoration practitioners will have valuable insights to inform when, where, and how monitoring can be improved on the landscape.

[5] Available at: http://storymaps.arcgis.com.
[6] Available at: https://knb.ecoinformatics.org/portals/SASAP/data.
[7] Available at: https://stateofsalmon.wa.gov/executive-summary/salmon-status/.

One tool to accomplish this feedback loop is a formal knowledge integration workshop, held annually, where Program monitoring partners share information from program- and project-level monitoring directly with restoration practitioners. The workshop should facilitate knowledge integration by encouraging future implementation solicitations to incorporate information from the Program's monitoring partnership into Implementation projects. Program Science staff will also receive feedback from Implementation staff on if and how to adapt monitoring designs to effectively measure implementation project outcomes.

In addition to annual internal assessment and episodic publicly available data visualizations, the monitoring program should provide a periodic formal assessment of the Program's progress toward its recovery goals (Section 1.2.1). This assessment should include a public workshop and formal report at a logical, pre-determined interval (e.g., 5 years). The report and workshop will synthesize the Programs' achievements, summarize the trajectory toward Program goals using both statistical and narrative analysis, refine metrics and targets for recovery over the next 5-year interval, summarize adaptive management experiments, and describe instances where monitoring data was used to adapt, refine, or reprioritize restoration and conservation actions.

7.4 Data Management

Data are the currency of a monitoring and assessment program. The success of the monitoring program depends largely on how data are collected (by multiple partner agencies), stored, shared, and analyzed. Data management includes developing protocols for data capture that can be integrated by multiple agencies, providing a central repository for data and information storage, a process to support program-level and project-level assessment, as well as a structure and process for accessibility and disseminating information. Each aspect of data management and recommendations for the program is discussed below.

7.4.1 Data Capture

Data to support the monitoring and assessment program will be generated by multiple entities including Program partners (state and federal agencies, Native American Tribes, NGOs, and restoration practitioners), academia, citizen science, and others and will require coordination to maintain consistent formatting and transfer into storage equipment. Some of these entities have pre-existing data capture and storage protocols that the Program will need to accommodate. For example, CDFW's Aquatic Survey Program (ASP) database is a distributed database used for the California Monitoring Program. CDFW has specific protocols for collecting and entering data into the ASP. The California Monitoring Program is expected to be a primary partner in any future Eel River monitoring program, and maintaining compatibility with the ASP will be a priority. Other organizations may be flexible and able to accommodate novel data capture protocols.

Electronic data capture methods often surpass standard paper-based data collection in accuracy, integrity, timeliness, and cost-effectiveness (Mosa et al. 2015). Where possible, the program should develop electronic data capture protocols that are compatible with partner organization databases and use form-based data entry (such as Survey 123) to reduce quality control issues (such as spelling and version control) with large data entry efforts.

7.4.2 Data Storage

Monitoring data can be stored on local servers, hosted cloud-based servers, or hybrid storage systems. Typically, environmental monitoring data are stored in either a relational database or a data repository. Data repositories store data from multiple sources and use metadata to index the data (make it searchable) and control access. Relational databases store data in consistent column/row formats and limit the types of data that can be managed. Because multiple types of monitoring data will be collected or stored by the monitoring program (e.g., spreadsheet, text files, images, and maps), a data repository is preferable to a relational database; however, within the data repository, relational data may be stored for specific monitoring tasks.

Numerous database systems are available, including proprietary systems like Microsoft Access and open-source systems like My SQL, Sqlite, or PostgreSQL. While state and federal partners often use Microsoft Access, an open-source and web-based platform has many advantages. Microsoft Access is a relational database with its own file format that is not compatible with any other system, requires proprietary software, and does not allow much flexibility with access controls to address issues such as indigenous data sovereignty (see Section 7.4.3. below). An open-source platform like PostgreSQL, hosted by a reputable and insured cloud-based data repository manager (such as dataone.org or datadryad.org) would allow for flexible, open-source data storage of multiple data types, with multiple levels of access and user control. A hybrid system is also preferable with local storage back-up to provide redundancy for data security.

7.4.3 Data Access

As with data capture, the Program should have a data repository that is compatible with partner organization's databases, including the CDFW's ASP. In working with monitoring partners, CDFW has employed a distributed model where "copies" of the ASP database are stored by partner agencies to use for data capture and entry, and then periodically copied to a central CDFW-managed platform that has retrieval and editing capability. The Planning Team recommends this approach for the monitoring program. Along with compatibility between partner entities, a critical access consideration is maintaining "indigenous data sovereignty," which is the right for Tribal partners of the program to own and govern data about their communities, resources, and lands and control access to their data. As such, the Planning Team envisions a data repository architecture that includes different levels of access and oversight, including the concept of having *core data* and *adjacent data* as follows:

- *Core Data*: Data the monitoring program requires to accomplish the monitoring objectives. These data should be overseen by Program monitoring staff (even if a contractor curates the database) and thus will receive more QA/QC review from Program staff.
- *Adjacent Data*: Data that supports the monitoring program but is not required to accomplish the monitoring program's objectives. These data should be curated in the Program's repository, but access may be controlled by partner organizations and will receive a lower degree of QA/QC review from Program staff.

Whichever platform is selected as a data repository, it is critical to maintain compatibility with the data visualization platforms discussed in Section 7.3.3.2. Compatibility with dynamic web-based data visualization platforms such as ArcGIS StoryMaps will dramatically increase the capacity of the monitoring program to share the recovery trajectory of the Eel River watershed with the public in accessible ways (see Section 7.1, goal 3).

7.5 Adaptive Management Opportunities

River ecosystems are incredibly complex, and the understanding of the myriad of interconnections between disciplines (e.g., fish habitat, fish behavior, physical processes, and foodscape) is limited. In contrast to engineering design and implementation, river ecosystems are governed by a mixture of physical processes and biological processes, many of which are driven by behavioral responses to the environment (e.g., a fish deciding to migrate downstream). In the face of this considerable uncertainty, a restoration framework for the Eel River must not be paralyzed by indecision. A structured assessment process called Adaptive Environmental Assessment and Management (AEAM, Holling 1978) that has been developed and applied to improve ecological management can be used to leverage monitoring data and improve Eel River restoration. AEAM is also synonymous with the more colloquial term *adaptive management*, which is used for this discussion.

Many restoration programs and practitioners say that they are using adaptive management in their restoration efforts, but few actually do. Adaptive management is a structured decision-making process based on the scientific method; it is not trial-and-error or simply monitoring a management or restoration action. Holling (1978) defines adaptive management as follows:

> *AEAM is a formal, systematic, and rigorous process of learning from the outcomes of management actions, accommodating change, and improvement management.*

There are many other similar definitions in the literature (Walters 1986), but the core components follow:

- A structured decision-making process with a hard-wired feedback loop to future management decisions;
- Empowered managers to make decisions despite varying levels of uncertainty;
- Mandated change in management in response to learning and reduced uncertainty;
- Iteratively updated conceptual models and quantitative models to facilitate an evolving understanding of the ecological system that is being treated;
- Clearly articulated, agreed upon, quantitative management objectives;
- An integration of decision-making, monitoring, and assessment into an iterative process of learning-based management (Williams et al. 2009); and
- A range of restoration program participants (shared learning, not just internal scientists).

The adaptive management feedback loop shown in Figure 7-4 illustrates the structured Science and decision-making process, and an overview of each step is summarized in Table 7-3.

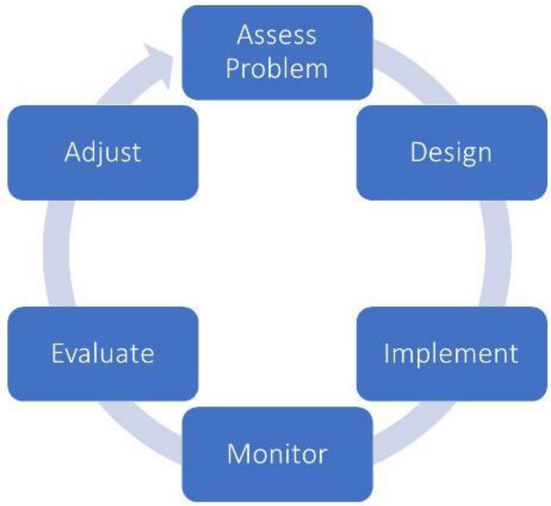


Figure 7-4. Six-step adaptive management feedback loop process.

Table 7-4. Summary of the steps in the adaptive management process that could be used for the Eel River Restoration and Conservation Plan, based on guidelines from USFWS and HVT (1999) and Pickard et al. (2023).

Step	Description
Assess problem	• Define management goals and specific ecological objectives that cascade from those management goals. • Develop conceptual models and hypotheses of key ecological relationships with management actions. • Prioritize relationships between management actions and ecological objectives. • Identify which priority relationships would benefit from an adaptive management approach. • Define targets for priority ecological objectives.
Design	• Simulate outcomes of management actions with qualitative conceptual models or quantitative predicted models to inform experimental design and expected/alternative outcomes. • Develop an experimental design for the adaptive management experiment (management actions, statistical design, monitoring and assessment), including active and passive adaptive management approaches (see Section 7.5.2). • Develop strategies for assessment, monitoring, and data management. • Develop study plan and cost and identify an acceptable level of investment with decision-makers. • Share/inform decision makers and partners on ecological objectives, conceptual models, hypotheses, and experimental design. • Develop potential next steps (including new management actions) for alternative outcomes to the experiment and obtain tentative agreement from decision-makers (e.g., look ahead).
Implement	• Collect baseline information identified in Monitoring Plan prior to implementation. • Implement management action(s).

Step	Description
Monitor	• Implement Monitoring Plan. • Manage and update database. • Document monitoring results.
Evaluate	• Compare monitoring results against desired ecological objectives and model simulations. • Document sensitivity of management action to desired ecological objectives. • Document reductions in uncertainties, update conceptual models and hypotheses based on learning. • Share learning with decision-makers and partners.
Adjust	• Update conceptual models and hypotheses based on learning and reduced uncertainty (update or restate system status). • Update quantitative simulation models based on learning and reduced uncertainty. • Update proposed management actions based on learning. • If needed, update ecological goals based on learning (should come on a longer time step).

Adaptive management can be used program-wide or applied to select ecological uncertainties depending on the specific needs of the watershed, details of the implementation program, and the technical abilities of participants. The appropriate use of adaptive management is described in the following subsections.

7.5.1 Guidelines for Applying Adaptive Management

Adaptive management is most effective in circumstances where (1) the ability to control an environmental outcome with a prescribed management action is high and (2) uncertainty in achieving the desired outcome is high (see Figure 7-5 for a conceptual model of adaptive management from Peterson et al. 2003). Some examples of this concept follow:

- *High Control*: A desired environmental outcome could include the flow inundation threshold of a floodplain restoration project (high control), but the uncertainty of achieving the desired outcome may be low (i.e., the floodplain can be can precisely designed to achieve the desired flow inundation threshold). In this case, adaptive management is not needed because of the low uncertainty (i.e., structured experiments are not needed to improve the ability to achieve the desired outcome of floodplain inundation). This example reflects the *Optimal Control* zone shown in Figure 7-5.
- *Low Control, High Uncertainty*: A desired environmental outcome could include the effect of floodplain restoration projects resulting in improved adult salmon escapement. The large number of confounding factors that affect adult salmon escapement and the high uncertainty about the sensitivity of floodplain restoration projects on the drivers of adult escapement results in limited use of adaptive management because experiments would be unlikely to establish a cause-and-effect outcome and thus would be wasted effort. This example would fall into the *Scenario Planning* zone shown in Figure 7-5. Through the *Scenario Planning* (Peterson et al. 2003), conceptual models and/or quantitative models could be developed and evaluated for hypothesized cause-and-effect relationships between potential management actions and adult salmon escapement, and logical winnowing / prioritizing of these potential management actions could be done to better identify adaptive management experiments that could yield better results (higher controllability).

An important supplement to the conceptual model shown in Figure 7-5 is consideration of whether the adaptive management experiment can measure an environmental response on the performance metric in response to the experiment within a reasonable amount of time such that future management can respond to that learning. Using the preceding examples, if a large number of floodplain restoration projects were implemented and the adult escapement response were monitored, it could take multiple generations (decades) of salmon to detect a change in adult escapement, and there may likely still be high uncertainty in the cause of that change in adult escapement (e.g., ocean conditions, other confounding restoration actions that are occurring at the same time as the adaptive management experiment). Therefore, adaptive management experiments need to set up both the management action and the desired performance metric such that a learning outcome (1) can be achieved in a reasonable amount of time to inform future management decisions and (2) have a high certainty of assessing a cause-and-effect relationship. Both of these issues require careful consideration of the management actions and performance metrics as part of the Design process in Figure 7-4.

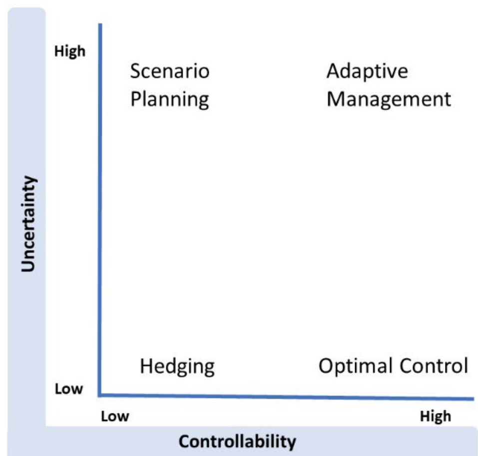


Figure 7-5. Conceptual guidance framework for when adaptive management may be appropriate based on uncertainty and controllability (from Peterson et al. 2003).

Using the preceding example again, a more appropriate adaptive management experiment would focus on a more direct performance measure (e.g., fry and juvenile salmonid growth on floodplains versus main channel) related to an aspect of floodplain restoration design (e.g., inundation threshold/timing/duration, complexity, large wood/cover) that could provide affirmative learning on the management action in a reasonable amount of time that would inform improved floodplain designs (a few years at most).

Additional guidelines for using adaptive management follow:

- Adaptive management should target ecological objectives that can inform management changes (“adjust”) within a reasonable time frame (months or years, not centuries).
- Adaptive management works best when there are experimental replicates, good baseline information, comparable control sites, and low sources of external variability and when the system response time is rapid.
- Adaptive management can be useful if there are significant scientific disagreements on conceptual models and hypotheses of relationships between management actions and expected ecological response. Adaptive management can help resolve these disagreements

by objectively developing and testing alternative hypotheses to foster a common understanding of system response. Objective implementation of adaptive management can turn an adversarial process into a collaborative process.

- Adaptive management is more difficult with a larger spatial scale, fewer replicates, more environmental variability and confounding factors, and a slow system response time. Accordingly for the Eel River, adaptive management may be most suitable for project-level implementation actions rather than program-level actions given the larger uncertainty, wide range of confounding factors, and slow response time at the program-level.

As the decision-makers, the Program Management body and Governance body described in Section 6.1 must understand adaptive management and embrace structured decision-making in the face of uncertainty.

Another conceptual model to illustrate the benefits of adaptive management is shown in Figure 7-6 (Marmorek 2001). If a long-term management decision is made now, and casual monitoring is conducted to evaluate effectiveness of that long-term management decision, it could take decades (if ever) to gather enough information needed to reduce uncertainty and establish cause-and-effect to the management action that would justify a change in that management action (top graph in Figure 8-13). In contrast, Active and/or Passive Adaptive Management experiments conducted before the long-term management decision can greatly reduce uncertainty and improve the quality of that long-term management decision.

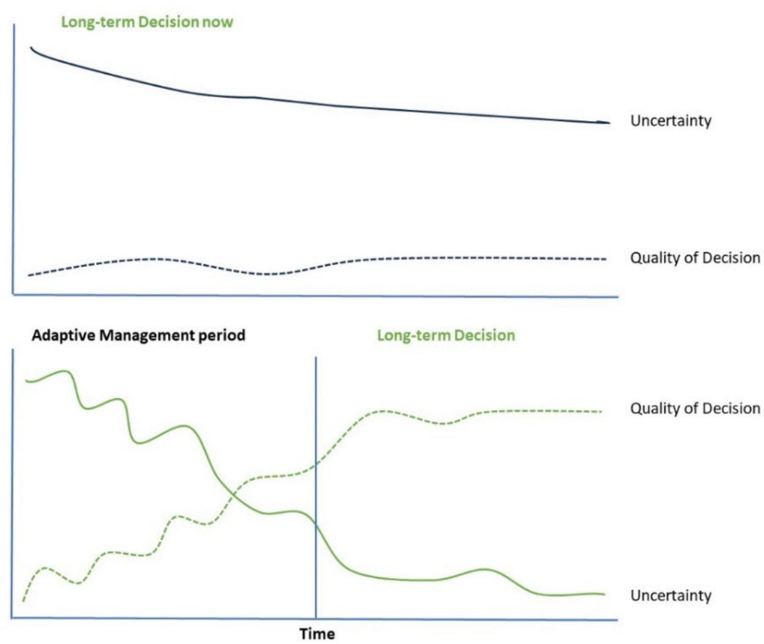


Figure 7-6. Conceptual model from Marmorek (2001), illustrating how adaptive management can reduce uncertainty and improve the quality of long-term decisions. The top figure illustrates uncertainty and quality of management decision made with no adaptive management compared with the bottom figure that illustrates more rapid improvement in uncertainty and quality of decision if adaptive management is used to inform long-term decisions. While more expensive in the short term, the time saved may result in overall cost savings, and more rapid achieving of desired ecological outcomes.

7.5.2 Recommended Application of Adaptive Management for the Eel River Restoration Framework

To apply the adaptive management principles, use the conceptual models provided in Section 3.2 and restoration and conservation actions provided in Section 4.3 to evaluate and prioritize uncertainties between restoration actions and ecological response (e.g., salmon productivity) and use guidelines above to identify and prioritize adaptive management experiments. This evaluation and prioritization process should be conducted as part of the upcoming Monitoring Plan implemented in Phase 2 (Table 7-1).

Adaptive management experiments should focus on those management actions and prioritized performance metrics that have the following:

- High controllability,
- High uncertainty (and the adaptive management experiment will drastically reduce this uncertainty),
- High ability to detect a change in performance metric in response to management actions (avoiding confounding factors and having high replicates to quantity sample variability and increase power of experiment), and
- Reasonable response time between the adaptive management action and learning (months to years, not decades) to enable learning and management change.
- Adaptive management experiments may be limited compared to the overall monitoring and assessment portfolio and budget and be most appropriate for project-scale management actions that satisfy the guidelines discussed above.
- If opportunities for adaptive management experiments are identified for inclusion the Program, then Program staff should develop an adaptive management component within the Phase 2 monitoring plan that documents the logical/analytical process used to prioritize adaptive management experiments and integrate these experiments into the annual work plans.
- When recruiting and hiring Program staff (Section 6.1.2), ensure that the Science body leadership staff fully understand and embrace the adaptive management structure and process, and are capable of overseeing the process and working with the program decision-makers to act upon results.
- Program budgets should accommodate flexibility for conducting and assessing adaptive management experiments (not be fixed and obligated for specific/repetitive monitoring actions).
- When developing adaptive management experiments, use *active* adaptive management (Williams et al. 2009, Marmorek 2001) whenever possible to increase the rate of learning, save time and resources, and more rapidly improve environmental response compared to *passive* adaptive management (or no adaptive management).

7.6 Program Linkages and Monitoring Plan Development Process

Monitoring and assessment are integral components to the success of the Program. Monitoring results will fill key data gaps and provide feedback to refine the conceptual life-cycle models and potential limiting factors developed in Section 3. Any refinements to the conceptual life-cycle models, limiting factors, and data gaps will inform the prioritization process and help refine appropriate restoration and conservation actions during the implementation phase. Monitoring results also provide direct feedback to Phase 2 by, for example, providing information that can be used for shifting or refining priority actions and/or implementation designs based on the effectiveness of similar actions that have been implemented and monitored.

Developing the monitoring plan will be performed within two Program phases, with the draft monitoring plan, and monitoring method assessment, conducted during Phase 2 and the final monitoring plan developed during Phase 3 (Table 7-5). The Planning Team would lead development of the draft monitoring plan in coordination with program partners and science advisors early during Phase 2. This approach would provide early coordination with program partners on ongoing monitoring and allow the initiation of key baseline monitoring elements. Program management and science staff would be hired during program formation (Phase 2) to lead the prioritization process. Coordinated projects would be implemented during Phase 3 and the monitoring plan would be revised as needed and adopted to guide Program-level and Project-level monitoring and assessment. After initial prioritization, implementation, and monitoring and assessment, an iterative process would be used where knowledge gained form implementation, monitoring, and assessment provides feedback to refine process components (e.g., species conceptual models, limiting factors, data gaps) within the process.

Table 7-5. Monitoring program linkages and monitoring plan development.

Program components	Phase 1: Planning	Phase 2: Program Formation and Prioritization	Phase 3: Implementation, Monitoring, and Assessment
Monitoring plan development	Monitoring Framework	Draft Monitoring Plan	Final Monitoring Plan
Intended use	• Informs Phases 2 and 3	• Provides additional guidance on roles and responsibilities of Science staff. • Identifies priorities for early (e.g., baseline) monitoring needs.	• Provides guidance on the actual monitoring and assessment plan that will be developed and implemented by Science staff in Phase 3 • Reporting and communications schedule
Actions		• Baseline monitoring • Prioritize actions	• Implement projects • Monitor and assess
Feedback loops	• Reevaluate goals and objectives • Refine species conceptual models • Reassess limiting factors • Reassess data gaps	• Refine designs • Reassess priorities • Refine restoration approaches	• Refine designs • Refine monitoring

During Program implementation, these feedback loops will provide information over a range of spatial and temporal scales. As described above (Section 7.3), project-level monitoring is typically performed at relatively smaller spatial scales and shorter temporal scales than program-level monitoring. Therefore, feedback from project-level monitoring to inform future project design and implementation will typically occur relatively quickly (e.g., annually or semi-annually). Comparatively, program-level monitoring can occur relatively infrequently (e.g., 5- to

10-year interval) or require extended periods to assess trends such that the feedback also occurs over an extended period (e.g., 10–20 years, or more).

In application, an approximately annual timestep for summarizing monitoring results and updating analyses related to Program goals and objectives (both project-level and program-level) is recommended, with the understanding that different monitoring types occur over different periods and durations, and some monitoring will occur over a much greater timestep. Therefore, monitoring results for different activities would be available at different times throughout the year. A specific schedule for how and when monitoring results will feedback into Phases 1 and 2, will be developed for the final monitoring plan.

7.7 Recommendations and Discussion

During Phase 2 of the Program, the Planning Team will convene with monitoring partners (i.e., agencies, Native American Tribes, contractors, and NGOs) to develop a draft monitoring plan and begin executing key elements of a monitoring program. The monitoring plan should leverage existing monitoring efforts and identify where monitoring needs to be expanded, or extended in time, to meet Program needs. As described in the introduction to Section 7, the monitoring plan will depend on which actions are *necessary, feasible, and practical* to meet the program's monitoring objectives. What is "feasible" will depend in large part on the support and capacity of partner organizations as well as funding for the Program, and likewise the monitoring program itself. What is necessary and practical depends on tradeoffs between programmatic monitoring options (e.g., as described in Section 7.3 above) and restoration and conservation action prioritization analysis conducted during Phase 2 of the Program.

Implementation of the monitoring plan will be coordinated by the Science body of the Program. The Science coordinator (Figure 6-2) would work with Program partners to develop an annual monitoring and implementation plan that outlines monitoring roles and responsibilities for each agency, including staffing, monitoring schedules, equipment plans, and data management. Because the monitoring program will be a multi-partner endeavor, productive coordination, mutually supported, well-understood assignments, and open lines of communication between Program partner agencies and the Program are vital to success. The Science coordinator will be responsible for instituting and maintaining this collaboration and will report to the executive director; however, Program partners must also be willing to coordinate work, commit staff/hours, and funding toward the Program's monitoring goals.

As described in Section 7.6, the monitoring program's initial structure and focus will be determined in Phase 2 via a draft monitoring plan; however, an initial suite of recommendations for program-level and project-level monitoring is provided below.

7.7.1 Data Management Recommendations

The Planning Team recommends creating a steering committee during Phase 2 composed of Program partners who are engaged with monitoring in the Eel River (e.g., CDFW, NMFS, Wiyot Tribe, Round Valley Indian Tribes, CalTrout, NGOs, and other practitioners) to establish organization-specific needs and commitments for a coordinated data repository. Key topics for the steering committee would be (1) ensuring compatibility with the CDFW ASP database, (2) maintaining indigenous data sovereignty, and (3) maintaining a pipeline between data storage and data visualization tools, and (4) creating a foundation for eventual program data management. A key product from this steering committee would be a description for the database/GIS manager position (Figure 6-2), communication with reputable data repository hosting organizations, and a recommendation for a Program data repository that addresses the challenges identified in Section 7.4. This data repository would be used to store and manage the program- and project-level data collected once Phase 2 monitoring and Phase 3 implementation begins.

7.7.2 Initial Program-level Monitoring Recommendations

As discussed, a fundamental tradeoff exists between spatial scale and the resolution of monitoring data—e.g., a tradeoff between monitoring at the primary sub-watershed scale (e.g., 136–2,072 km^2) and the IMW/HUC-12 sub-basin scale (e.g., 26–104 km^2). Here, the Planning Team suggests an initial monitoring effort that integrates spatial scales to develop multiple lines of evidence for the status and trends of focal species populations. For a review of the methods discussed below, please refer to Section 7.3.1. Prior to initiating these monitoring recommendations, the data infrastructure and accessibility procedures for the monitoring program must be developed to ensure that data are collected, stored, and shared responsibly (see Section 7.4).

At the primary sub-watershed scale, the Planning Team suggests continuing and expanding the existing array of sonar cameras that provide estimates of adult abundance (fish in). Fish-in data would be collected on the Lower Eel, Van Duzen, Middle Fork Eel, South Fork Eel, and Upper Main Eel sub-watersheds. Fish-out monitoring would also be implemented initially at the sub-watershed scale using a paired-watershed study design. The paired watersheds should focus on the Upper Main Eel and South Fork Eel sub-watersheds (see Figure 2-1). These two sub-watersheds were selected because the Potter Valley Project work will focus on the Upper Main Eel sub-watershed, whereas the South Fork Eel sub-watershed represents both a quasi-control and the sub-watershed with the most potential for life-history diversity across multiple focal species. The success of fish-out monitoring at this scale will be determined based on recapture rates in approximately the first 2 years of operation, and if it proves ineffective, fish-out minoring would be transferred to a suite of IMWs within each of the paired sub-watersheds. The Planning Team also suggests conducting spatial structure sampling (following California Monitoring Program design) at smaller HUC-12 sub-basins within each of the paired sub-watersheds, in addition to the Middle Fork Eel sub-watershed—which provides critical habitat for Chinook Salmon and steelhead. Finally, conducting a combination of telemetry studies and isoscape development to compute baseline life-history diversity metrics (Section 3.2) is suggested within each of these three sub-watersheds (Middle Fork Eel, Upper Main Eel, and South Fork Eel) prior to Phase 3 implementation (Section 4). Collectivity, these monitoring approaches will provide an index of adult abundance and juvenile production (fish in–fish out), at a large enough scale to meaningfully reflect the Eel River population, paired with higher spatial resolution studies (spatial structure, isoscape and telemetry) to evaluate the recovery of life-history diversity in response to restoration actions—which is a key goal of the Program. This scale of monitoring is estimated to cost $1–2 million per year and require at least 10–15 staff (depending on season) across all Program partner organizations.

7.7.3 Initial Project-level Monitoring Recommendation

Existing project-level monitoring is being carried out across the Eel River; however, this monitoring is not standardized, stored in a common repository, or synthesized to inform future restoration implementation throughout the watershed. Therefore, the Planning Team recommends creating a template for project-level monitoring data. The template would include each of the factors described in Table 7-3: impact, restoration action, hypotheses to test, parameter selection, sampling design with adequate spatial and temporal replication, and monitoring and sampling methodology. The Planning Team also recommends creating a space in the Program's data repository (Section 7.4.2) for contributing restoration practitioners to share project-level data and template results. Finally, the Planning Team recommends implementing a knowledge integration workshop as soon as feasible (Section 7.3.3), where program monitoring staff share information directly with restoration practitioners and work to ensure that fish population and habitat data are being used to inform restoration design and implementation. Ultimately, the knowledge integration workshop will become a Program deliverable, but initiating this workshop at an ad-hoc level still provides great value to achieve the goals of this monitoring framework.

8 RECOMMENDATIONS AND NEXT STEPS

The purpose of this section is to present major recommendations from Phase 1 of the Program (Section 8.1) and outline the primary next steps required to advance the Program (Section 8.2) and begin execution of the Plan.

8.1 Recommendations

The recommendations presented here are based on the understanding gained from and outcomes of each component of the Phase 1 planning process and reflect input from the Planning Team, the TAC, and participants in Eel River Forum meetings held during the planning process. This list is not comprehensive; it includes recommendations are that are considered important for establishing and implementing a successful restoration and conservation program in the Eel River watershed that can achieve the vision and goals of the Program presented in Section 1.2.1. These recommendations are based on the current understanding of major components of the Plan and will be refined and expanded as new information is gained and additional input from watershed partners is received as the Program is developed during Phase 2.

8.1.1 Program Management

The Planning Team considered a range of potential management frameworks based on review of other large-scale restoration programs in the western United States and recommends a centralized management framework based on the current understanding of management needs and potential future funding strategies. The Planning Team recommends a management framework that is similar to the Klamath River Renewal Corporation because of several functional benefits provided by that structure, including (1) minimizing the size of the Program's staff, (2) relying on the existing structures of state and federal agencies, Native American Tribes, academic institutions, and NGOs to implement and monitor priorities developed by the Program, and (3) enabling better adaptability of Program staffing, responsibilities, implementation, and monitoring as the Program is implemented and evolves over time.

8.1.1.1 Management Framework

The recommended management framework is described in Section 6 and includes four internal and two external program management components. Internal Program management components include a Program Management body (executive director) and three technical bodies (Science, Planning, and Implementation). External program components include a Program Governance body and External Review body. Also included in the framework are recommended pathways for external coordination with advisors (Science and legal) and other external entities (agencies, Program partners, and the public/media). A summary of recommended roles and responsibilities to be established follows:

- Governance body—a non-profit corporation with board of directors;
- Program Management body—an executive director responsible for coordinating with board, coordinating with external entities, and managing Program staff within the Science, Planning, and Implementation bodies:
  - Science body—oversees monitoring and assessment (monitoring and assessment priorities),
  - Planning body—provides program coordination and administration, and

  - Implementation body—coordinates prioritization and implementation, and conducts public outreach and information sharing (coordination with Program Partners, website development and maintenance, data sharing, Tribal liaison);
- Science Advisory Board—an external multi-disciplinary team to provide technical input and review to the Program.

8.1.1.2 Funding Strategies

The Program Management framework assumes that a large-scale, centralized restoration and conservation program is needed for the Eel River and will require stable funding to be effective. Ideally, a large capital endowment (e.g., similar to the Headwaters Fund) could be obtained where interest revenue generated by the endowment would be sufficient to fund all Program administration and operational costs in perpetuity and, ideally, a portion of annual restoration and conservation action implementation costs. There is not currently a large capital endowment in place, although several potential sources are being explored. Even with an endowment, a portfolio of potential funding and in-kind support sources will likely be needed to fully implement the Program. Therefore, a primary role of the board of directors and executive director will be to strategize and obtain funds and in-kind support necessary to fully implement the Program and minimize interruptions to the funding stream that would delay implementation of restoration and conservation actions.

8.1.2 Restoration and Conservation Priorities

This section provides initial recommendations for priority restoration and conservation actions and related assessments and strategies aimed at protecting and accelerating recovery of focal species and achieving other Program goals (Section 1.2.1) and restoration and conservation objectives (Section 4.2). These initial recommendations are based on review of existing plans and other documents, species conceptual models, input from the TAC and other natural resource professionals, and professional judgement from the Planning Team. As described in Section 5, more specific restoration objectives and actions needed to achieve them will be systematically prioritized during Phase 2 of the Program.

8.1.2.1 Dam Removal and upper mainstem Eel River restoration

The anticipated decommissioning of PG&E’s Potter Valley Project and removal of two mainstem Eel River dams is a pivotal moment and significant opportunity to help restore Eel River fish populations. The decommissioning is an important opportunity that will accelerate restoration through several outcomes. Recommendations around the outcomes of the decommissioning to best benefit focal fish populations and watershed processes follow:

- Ensure volitional access to the estimated 288 miles of historically available, high-quality fish habitat upstream of Scott Dam;
- Remove any lentic habitats that harbor and support non-native predators;
- Restore functional flow components and minimize risk to the upper mainstem Eel River ecosystem below any continued infrastructure for diverting flow to the Russian River;
- Conduct careful planning to limit the short-term impacts of releasing sediment stored in Lake Pillsbury;

- Evaluate restoration opportunities within the footprints of Lake Pillsbury and Van Arsdale Reservoir to supplement actions planned under decommissioning; and
- Evaluate restoration opportunities upstream of lake Pillsbury to maximize the benefits of newly accessible habitats.

8.1.2.2 Coldwater habitat protection and restoration

Protection and restoration of coldwater habitats—both at the watershed scale and microhabitat scale within channel segments—are essential for restoring and promoting focal species life histories and protection from ongoing climate and environmental change. Key recommendations include the following:

- At the watershed-scale, identify, protect, restore, and provide access to coldwater tributaries, headwater streams, and coastal and estuarine habitats that can support focal species through the summer during drought years. Restoring anadromous fish access to and improving habitat within the coldwater habitats upstream of Scott Dam is a high priority;
- At the channel-segment scale, locate and characterize thermal refugia and implement actions to restore physical habitat at and improve fish access to these locations, for example, thermal refugia may include thermally stratified pools, coldwater plumes associated with tributaries and springs, coldwater reaches associated with upstream hyporheic or sub-surface flows;
- Prioritize pikeminnow suppression in locations with thermal refugia capable of supporting large numbers of juvenile salmonids and other native aquatic species; and
- Take actions that help maintain and improve coldwater habitats, such as stream flow protection and enhancement and riparian plantings.

8.1.2.3 Life-history diversity and habitat heterogeneity

As described in Section 3, life-history diversity plays a fundamental role in abundance, persistence, and stability of native anadromous fish populations. Non-natal juvenile life histories increase the overall carrying capacity for fish populations of a watershed, thereby increasing population abundance and resilience. Recovery of the Eel River's fish populations depends on recovering life histories that are currently depressed or rare, not just increasing the capacity of life histories that are common today. For this reason, understanding, protecting, and restoring non-natal juvenile life-history strategies—as well as less commonly recognized adult life-history strategies—are fundamental to recovering native fish populations and are a core focus of the Plan. A primary strategy for promoting life-history diversity involves protecting and restoring a mosaic of habitats across the watershed that provide variable conditions within and between years. Key recommendations for promoting life-history diversity include the following:

- Prioritize actions that protect and recover non-natal life history strategies;
- Restore habitats in the estuary and lower mainstem corridor;
- Restore and increase connectivity with off-channel habitat features along mainstem corridors.
- Restore and improve access to habitat in low-gradient tributaries, focusing on those in lower watershed—including small and intermittent streams—to support juvenile life-history diversity;
- Restore and protect thermal refugia across spatial scales;

- Conduct focused planning assessments to identify opportunities and implement restoration in large, rare valleys, which include Round Valley, Little Lake Valley/Outlet Creek, upper Ten Mile Creek, Gravelly Valley in the upper Eel River (once the Potter Valley Project is decommissioned);
- Identify and restore unique habitats, such as locally unconfined mainstem channel segments with high potential for floodplain connectivity in otherwise confined reaches; and
- Increase juvenile rearing and survival in mainstem rivers by increasing habitat complexity and suppressing non-native predators.

8.1.2.4 Estuary and lower mainstem corridors

For the reasons described in Section 3.2.4.2, restoring and conserving aquatic and riparian habitats in the estuary and lower mainstem corridors of the Eel, Van Duzen, and South Fork Eel Rivers are fundamental to the recovering populations of focal fish species. Key recommendations include the following:

- Continue to implement and monitor outcomes of high-value restoration projects across the stream-estuary ecotone and the estuary;
- Restore natural tidal process and improve fish access to tidal slough and marsh habitats through tide gate removal or modification;
- Restore floodplain connectivity and off-channel features (particularly locations fed by tributaries) along the estuary and lower mainstem corridors;
- Restore access to and habitat within the lower reaches of tributaries to the estuary and lower mainstem corridors;
- Identify and implement additional habitat restoration and conservation opportunities in the estuary and lower mainstem coordination with the ongoing Lower Eel River SHaRP process.

8.1.2.5 Sediment management

Sediment supply plays an important role in creating and maintaining riverine habitat, affecting both the quality and quantity of aquatic and riparian habitat conditions over time. Sediment supplied to a channel reach or floodplain can enhance or degrade conditions depending on the incoming and existing grain-size distribution, supply rate relative to transport rate, and the capacity of a channel to store and process sediment into functional habitat. Information about past and present supply rate can be critical to understanding the disturbance history, appropriate upland and riverine restoration treatments and their anticipated longevity, and the trajectory of recovery with and without intervention. Key recommendations include the following:

- Inventory and assess existing and potential erosion and sediment delivery in key sub-watersheds and/or source areas known to have high rates of management or disturbance related sediment delivery to reaches identified as a high priority for restoration, enhancement, or conservation;
- Implement sediment source reduction measures in watersheds with high rates of erosion and sediment production, or where disturbance (e.g., high intensity wildfire) has the potential to result in severe erosion and sediment deliver to reaches with a high priority for restoration, enhancement, and conservation;
- Monitor flow and suspended sediment concentrations in select reaches known to be fine sediment impaired and/or are sources of input to reaches identified as a high priority for restoration, enhancement, or conservation;

- Assess channel and floodplain sediment storage characteristics (e.g., volume, grain size distribution and bed surface texture, scour and deposition, turnover rate) in responsive reaches identified as a high priority for restoration, enhancement, or conservation;
- Develop sediment budgets to help understand sediment fluxes into and out of key reaches, storage changes, and the associated effects to aquatic and riparian habitats over time; and
- Synthesize and use the above information about sediment dynamics to inform appropriate fisheries restoration, enhancement, and conservation strategies.

8.1.2.6 Environmental flow management

The focal species of the Plan have life histories that have co-evolved with the Eel River's natural flow regime. Flows on the Eel River are currently impacted by Potter Valley Project flow management, the cumulative effect of many small diversions throughout the watershed, and climate change impacts. While there may be limited local solutions to climate change induced flow changes, several restorative actions can be done to improve flows on the Eel River:

- Develop a future flow regime downstream of the Potter Valley Project that fosters improved flow conditions and retains the functional flow components of the natural hydrograph downstream of the anticipated Van Arsdale diversion facility;
- Continue curtailments of illegal water diversions throughout the Eel River watershed, particularly during the more sensitive spring and summer months for salmonid growth and outmigration;
- Support forbearance programs for legal water diversions that enable winter water off channel diversion and storage for use in the spring and summer and that reduce or eliminate summer diversions on small streams throughout the Eel River watershed;
- Apply and use relevant State Water Resources Control Board tools and criteria for establishing instream flow objectives and targets based on the California Environmental Flows Framework; and
- Establish and maintain necessary long-term flow monitoring stations in key sub-watersheds and/or reaches identified as a high priority for restoration, enhancement, or conservation.

8.1.2.7 Beaver-assisted habitat restoration

A promising strategy for increasing summer base flows involves reintroduction of beavers or simulating their habitat influences by constructing beaver dam analogs. Because their dams slow and spread-out stream flows, beaver can create wetlands and promote groundwater recharge that can enhance stream flows and fish habitats in downstream reaches (Lundquist and Dolman 2020, Dewey et al. 2022). Beaver dams and associated ponds, bank lodges, side channels, and burrows can also create large areas of prime summer and winter rearing habitat for juvenile salmonids and other fish. By changing geomorphic and hydrological process of stream channels and riparian corridors, beaver can also increase overall ecosystem resilience to climate change and forest fire. For these reasons, key recommendations include the following:

- Conduct focused assessments of present-day distribution and the potential for beaver reintroduction in the watershed are needed; and
- Reintroduce beaver and construct beaver dam analogs in appropriate habitats and channels.

8.1.2.8 Non-native species management

Non-native aquatic and riparian species have potential to adversely impact native fish and other aquatic species through predation, competition, or habitat modification. For example, Sacramento Pikeminnow, which occur at high densities in many parts of the Eel River watershed have fundamentally altered the aquatic ecosystem, by preying on, competing with, or altering the behavior of native fish species. The presence of pikeminnow has likely selected against important life-history strategies that may have been historically abundant, such as mainstem rearing in the spring and summer by juvenile salmonids. Primary recommendations for non-native species management include the following:

- Continue ongoing monitoring and management of non-native Sacramento Pikeminnow in the South Fork Eel River, upper mainstem Eel River, and North Fork Eel River. Expand monitoring and management across the watershed, focusing effort on locations with high concentrations of the species and low survival of juvenile salmonids;
- Continue studies and field experiments to improve understanding of pikeminnow biology and evaluate effectiveness of management actions;
- Develop management plans for controlling invasive plant and aquatic species during and after the decommissioning of PG&E's Potter Valley Project;
- Prevent and control invasive plant and aquatic species spread throughout the basin; and
- Remove warm water and lentic habitats associated with the Potter Valley Project.

8.1.2.9 Conservation Priorities

While high-priority lands and parcels for conservation in the Eel River will be determined during the Phase 2 prioritization process, the Planning Team has identified several initial conservation priorities during this Planning phase and has the following recommendations:

- Seek a state or federal land designation for long-term Eel River watershed–wide conservation; this designation would serve as a mechanism for identifying priority acquisitions and transferring private properties into public ownership and management;
- Emphasize the Eel River watershed as a place that could greatly contribute to the California 30x30 Initiative (CNRA 2022);
- Expand and add to the edges of existing conservation areas through public ownership, land conservation easements, and restoration;
- For lands within federal management, plan for partial transition of public ownership from non-protected to protected statuses;
- Explore opportunities to identify the Eel River as a pilot climate refugia within the North Coast region;
- Identify "critical biodiversity hotspots" that are especially vulnerable to climate change, to prioritize for conservation;
- Identify "fish productivity hotspots" with unique geology, hydrology, and water quality that currently provide resilient fish production in the basin that should be prioritized for conservation;
- Identify conservation opportunities in rare low-gradient valleys (e.g., Round Valley, Little Lake Valley/Outlet Creek, upper Ten Mile Creek);
- Promote and coordinate with existing land conservation organizations in the Eel River (e.g., the Great Redwood Trail Agency, the Wildlands Conservancy);

- Develop conservation easements or transfer land to public ownership in the lower Eel River given that this part of the watershed is used by all focal fish species;
- Coordinate with and support the Lower Eel River SHaRP process;
- Assist with and promote land-back acquisitions by Native American Tribes; and
- Engage with the public and community to promote interest in conservation easements.

8.1.3 Monitoring, Assessment, and Research Priorities

Initial recommendations for monitoring and assessment priorities are described in Section 7.7 and recommendations are summarized below for data management, program-level monitoring, and project-level monitoring. In addition, adaptive management experiments are also encouraged where it makes sense to do so, given the ability to conduct controlled management experiments (replicates, statistical power). Monitoring and assessment recommendations follow:

8.1.3.1 Data Management

- Create a steering committee to establish organization-specific needs and commitments for a coordinated data repository and prepare the following products:
    - Job description for the database/GIS manager position
    - Recommendation for a Program data repository that is compatible with CDFWs ASP database.

8.1.3.2 Program-level monitoring

- Continue and expand fish in–fish out monitoring:
    - Continue and expand sonar camera monitoring to estimate adult escapement (fish in) focusing on the Lower Eel, Van Duzen, Middle Main Eel, South Fork Eel, and Upper Main Eel sub-watersheds, and
    - Initiate juvenile outmigrant trapping to estimate juvenile/smolt production (fish out) using a paired sub-watershed study design focusing on the Upper Main Eel and South Fork Eel sub-watersheds;
- Conduct spatial structure sampling within paired sub-watersheds (Upper Main Eel and South Fork Eel) to understand the distribution of focal species on the landscape; and
- Monitor life-history diversity within paired sub-watersheds (Upper Main Eel and South Fork Eel) to estimate current array and success of juvenile life histories and provide empirical support/refinement for the species conceptual models:
    - Conduct telemetry studies in both sub-basins to understand movement and timing and survival of emigrating juvenile fish, and
    - Implement isoscape development in both sub-basins to inform juvenile life histories and habitat use and understand the relevant contribution of different life histories to adult production.

8.1.3.3 Project-level Monitoring

Current ongoing and near-term monitoring needs to be standardized, stored in a common repository, and synthesized to inform future restoration implementation throughout the watershed. Project level monitoring priorities include the following:

- Creating standardized templates for project-level monitoring data that consider the following factors: impact, restoration action, hypotheses to test, parameter selection, sampling design with adequate spatial and temporal replication, and monitoring and sampling methodology;
- Creating a space in the Program's data repository for contributing restoration practitioners to share project-level data and template results; and
- Convene a knowledge integration workshop, where program monitoring staff share information directly with restoration practitioners and work to ensure that fish population and habitat data are being used to inform restoration design and implementation.

8.1.3.4 Additional research and information needs

The development of life-history conceptual models has revealed various data gaps and information needs related to focal fish species and watershed conditions. In addition to the program-level and project-level monitoring recommended above, various assessments and analyses are needed to (1) establish a more robust understanding of controls abundance and life-history diversity of focal specie, (2) inform prioritization of restoration and conservation action in Phase 2, and (3) increase the efficacy of future phases of the Program. Key recommendations follow:

- Review data gaps from focal species conceptual models (Section 3.2.4.3) and establish feasible research projects and linkages with ongoing and future monitoring improve understanding of the controls on production and life-history diversity of focal fish species;
- To help fill these data gaps, take the following steps:
    - Foster collaboration with academic institutions and researchers, including graduate students and post-doctoral researchers, to fill data gaps,
    - Create fellowships, grants, and/or additional funding opportunities to support research in the Eel River watershed by graduate students,
    - Support and promote field tours of the Eel River at technical conferences to widen engagement in the watershed from technical experts, and
- Promote collaboration around the anticipated Potter Valley Project decommissioning, including outreach to agencies, scientists, and engineers to synthesize lessons learned from recent and ongoing dam removals in the region (Elwha Dam, Klamath River dams).

8.2 Next Steps

This Plan, Phase 1 of the Program, outlines the fundamental components for creating and implementing a successful watershed-wide program. This section describes a series of important next steps that will be the focus of Phase 2 of the Program. The steps listed here are not intended to be an exhaustive list or a detailed road map, rather they are the major milestones that need to be achieved in the next phase of the Program's development. Additional steps and actions will be identified as planning and development of the Program continues.

- *Distribution and Outreach:* Outreach and distribution of the Plan is crucial to its success. First, any community members or organizations that have not been exposed to the Plan development process and the goals that were developed should have the opportunity to provide input. The document will be published on CalTrout's website and released via local media outlets to ensure broad distribution across the community.
- *Entity Formation, Board of Directors, and Staff:* Building on Section 6, the Program must develop an entity so it can begin to execute the strategies being formulated. Legal council should be retained to determine the type and structure of the entity. The Planning Team (with input from the TAC) in parallel with the entity formation, should identify the members of the board of directors that will be govern the Program. The board of directors will then solicit applications or seek out an executive director who can begin implementing the directives given by the board, including hiring of support staff and execution of prioritization.
- *Financing and Budget:* Phase 2 of the Program development will require additional financing and funding to support. The budgeting process will be a detailed accounting of the Program needs. The needs will include financial requirements for developing the entity, startup costs (office space, supplies, legal costs, licenses), the board of directors' compensation (if any), the executive director salary, support staff salaries, and the funding needed to execute the prioritization process (Section 5) and initial monitoring needs (Section 7). Development of a detailed budget will support procurement of funding to support Phase 2.
- *Prioritization Execution:* A clear and executable framework to identify and prioritize specific and broad restoration/conservation actions was developed as part of the Plan. In parallel with the steps listed above (Section 8.2), the prioritization framework should be implemented, including advancing the highest priority analyses and syntheses that will be used as inputs to the prioritization process. Moving forward with prioritization is important so that the implementation of actions can begin.
- *Baseline Monitoring:* Continuation and expansion of the baseline monitoring of juvenile and adult salmonids being conducted in the Eel River watershed is imperative. This baseline monitoring will serve multiple purposes. First, it will help establish the current fish population status, making directional changes clearer as restoration actions are completed. Second, baseline monitoring will be the foundation for the hypothesis testing framework described in Section 7.3.3.1. Lastly, baseline monitoring will fill existing data gaps and help identify additional data needs.

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Appendices

Appendix A

Eel River Restoration and Conservation Plan
Planning Team and Technical Advisory Committee

Eel River Restoration and Conservation Plan Planning Team and Technical Advisory Committee

Name	**Affiliation**
Eel River Restoration and Conservation Plan Project Team	
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Christine Davis	California Trout
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Eel River Restoration and Conservation Plan Technical Advisory Committee	
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Allen Renger	California Department of Fish and Wildlife
Chris Loomis	California Department of Fish and Wildlife
Seth Ricker	California Department of Fish and Wildlife
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Charlie Schneider	California Trout
Joshua Fuller	National Marine Fisheries Service
Matt Goldsworthy	National Marine Fisheries Service
Ruth Goodfield	NOAA Restoration Center
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Josh Boyce	US Fish and Wildlife Service
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Marisa McGrew	Wiyot Tribe

Appendix B

Eel River Forum Watershed Community Input

TO BE PROVIDED FOR FINAL

APPENDIX C

Channel Archetypes

NOTE TO REVIEWERS:

This draft appendix is an in-process work product that is incomplete and has not undergone final editorial review and formatting.

1 GOALS AND OVERVIEW OF CHANNEL ARCHETYPE ANALYSIS

In developing management and restoration plans, there is a need to conceptualize landscapes into groupings that are similar processes and attributes, to reduce the complexity of understanding and ultimately decision making. These conceptual models, or "archetypes," across a landscape can represent a set of biophysical processes which "control the behavior of the unit, generating and sustaining characteristic features and attributes" (Cullum et al. 2017). Archetypes are "inherently vague and imprecise," because group membership almost always occurs across a spectrum rather than as a binary, but this imprecision does not defy their usefulness in highlighting important processes and features that drive ecological use and management decision.

In the Eel River Restoration Plan, the goal of the channel archetyping analysis was to categorize and identify similar river channel segments across the watershed at the reach-scale (approximately 1 km) based on primary physical and environmental attributes that reflect physical processes and disturbance mechanisms that work to maintain channel morphology over time. These attributes determine (1) how fish use these channel segments and (2) opportunities and constraints for restoration actions. Identifying and mapping these channel archetypes across the Eel River watershed allows streams with similar ecological and physical processes to be identified and their relative proportion to be quantified at larger spatial scales (e.g., within a sub-watershed or HUC-12 catchment). This information provides a useful framework for visualizing and communicating how different focal fish species, life stages, and life history tactics have the potential to use parts of the watershed across time and space as part of the species conceptual models. Additionally, these channel archetypes provide a useful reach-scale planning unit for identifying locations that are most appropriate for different restoration actions and expectations for how these actions will evolve given the physical channel processes.

As with any grouping analysis, it was necessary to aggregate some channels with unique characteristics to maintain simplicity and a reasonably manageable number of channel categories. We acknowledge that a diversity of stream channels exists within most of the archetypes identified, and it will be necessary to conduct additional analyses to identify and describe variation in other key ecological and physical processes to support of various future restoration planning and prioritization steps. For example, within channel archetypes that are suitable for floodplain restoration, further assessments of channel confinement and flow inundation will be needed to identify reaches most suited for floodplain habitat enhancement. Similarly, these channel archetypes can be used as a template to overlay other important datasets for certain species to identify potential unique hotspots on the landscape. Low-gradient channel archetypes that have a relatively unconfined valley and that also have higher summer baseflows with cool temperature, for example, might be areas to prioritize Coho-focused restoration projects.

The data used to construct the channel archetypes are readily available physical variables that provide a template for process controls and species use. We expanded on the "Intrinsic Potential" concept, which scores habitat for a species based on drainage area, slope, and channel confinement (Burnett et al 2007). Our channel archetypes differ from the IP in that they are relevant across salmonid species (rather than having a IP layer for each species) and that they include information about predicted thermal regime. Similar to the IP, the channel archetypes represent potential use/physical conditions, rather than current (impaired) conditions. For example, some of the low-gradient, cold tributary streams may not currently be natal streams for Coho due to unnaturally high sediment inputs from upslope land use disturbance or lack of channel complexity for over-wintering velocity refugia. The channel archetypes are built with currently available watershed-wide datasets on drainage area, slope, and water temperature, as described below. As a result of our grouping analysis, we identified 14 unique channel archetypes that encompass physical and thermal categories (see Section 3).

2 METHODS

2.1 Datasets

A suite of readily available and watershed wide physical and environmental datasets that potentially influence fish habitat potential were gathered and considered. The initial list was narrowed to drainage area, slope, and water temperature (Table C-1). These variables are primary drivers of fish habitat potential and were available in a consistent channel network. Drainage area and slope data were obtained from FitzGerald et al. (2021), who attributed data to channel segments that were 1 km or shorter from the NHDPlus dataset (10-m resolution). Slope measurements were also calculated at this scale, using the change in elevation from the top and bottom of the 1km segment, so there is likely smaller-scale variability that is not captured, particularly in segments that contain a discrete elevation change (e.g., a waterfall). Predicted mean monthly water temperatures throughout the Eel River watershed were obtained from FitzGerald et al. (2021), who modeled them using a Stream Spatial Network (SSN) (Ver Hoef & Peterson 2010). We used mean monthly August temperatures to categorize channels by thermal regimes at a time of year when temperatures can be physiologically stressful for sensitive species. However, water temperatures in the Eel River are often slightly warmer in July (Asarian et al. 2016). Additionally, streams that are seasonally too warm may provide high growth environments, especially if food resources are adequate, at other times of the year (Armstrong et al. 2021, Rossi et al. 2022).

Table C-1. Datasets used for channel archetyping and their source.

Dataset	Source	Scale
Drainage Area	FitzGerald et al. 2021, calculated from NHDPlus	1 km or less stream segments
Slope	FitzGerald et al. 2021, calculated from NHDPlus	1 km or less stream segments
Mean monthly water temperature	FitzGerald et al 2021, empirical/statistical modeled from Stream Spatial Network	1 km or less stream segments

In identifying datasets for use in the channel archetypes analysis, we identified additional channel sets that will be useful at later stages of restoration planning and prioritization (Table C-2). These were not used in our channel archetypes to reduce complexity at our focal planning units but highlight that these will be important at different stages in the planning. Modelled summer baseflows were downloaded from a statewide functional flow model, the California Natural Flows Database (CEFWG 2021, Grantham et al 2022). The model estimates functional flows for every 1–3 km stream segment in California. Valley confinement was calculated for the channel segments from valley wall to valley wall, estimated by a 25% slope (Guillon et al 2019, Byrne et al 2020). Predicted geomorphic channel types, following Montgomery and Buffington (1998) categories and calculated from methods in Flores et al. (2006) were also provided by FitzGerald et al (2021). There are likely other datasets that can be considered as well, but we have not identified the best data source yet (e.g., predicted sediment supply), or the which scale to summarize the data (e.g., lithology, riparian forest).

Table C-2. Datasets that will be useful to layer on channel archetypes at later stages of restoration planning and prioritization.

Dataset	Source	Scale	Future use
Dry season baseflow	California Natural Flows Database	3 km or less stream segments	The stability of baseflows and tendency to be intermittent may help with prioritization
Valley Confinement	Byrne et al 2020	3 km or less stream segments	Identify areas with floodplain potential
Geomorphic Channel Classification	FitzGerald et al 2021, calculated with methods in Flores et al 2006	1 km or less stream segments	Estimate predicted geomorphic characteristics within a channel archetype

2.2 Process Overview

We first developed biologically and physically relevant categories within each variable (drainage area, slope, and temperature). To avoid having too many categories within each variable (and amongst all variables), in some cases it was necessary select relatively broad categories (e.g., lump all channels with drainage areas from 2–100 km^2). After selecting initial categories for each variable, we plotted the distribution of categories within variables in a hierarchical manner (e.g., the distribution of drainage area categories, distribution of slope categories within each drainage area group, and then temperature distribution within each slope-drainage area group), to understand prevalence of relevant categories within the Eel River watershed. Based on distributions within these hierarchical categories, we then selected the smallest number of channel archetypes possible that reasonably represents unique combinations of our focal variables. As described above, developing the archetypes in this way meant grouping some potentially unique channel types (e.g., warm, high gradient tributaries), and a future analysis could highlight these outliers.

2.3 Drainage Area

Drainage area categories were determined by potential fish use, physical processes, professional judgement, and local knowledge of the Eel River (Table C-3, Figure C-1). We used a logarithmic scale, with break points at 100 and 1,000 sq km, because this is a scale that governs many physical processes in nature. A logarithmic scale is also consistent with Higgins et al. (2005) suggested way of hierarchically categorizing large watersheds.

Table C-3. Drainage area categories that were considered for channel archetypes.

Drainage area (km^2)	Category	Description
<2	Small Tributary	Very small watersheds, often not perennial fish habitat but some channels may be important for non-natal rearing in the wet season. Relevant for restoration consideration due to sediment and water inputs.
2–100	Tributary	Includes most spawning and natal rearing habitats for Coho Salmon and steelhead and some spawning by Chinook Salmon and Pacific Lamprey. This is generally the channel size at which smaller-scale restoration activities can be effective (e.g., wood addition). This group includes high-energy reaches where allochthonous inputs and riparian shading are important. The largest number of channels fall in this category and it includes the greatest diversity of channel slopes and water temperatures.
100–1,000	Mainstem	Includes channels that are used for seasonal rearing and migration; significant spawning by Chinook Salmon, and Pacific Lamprey, and occasional spawning for Coho Salmon and steelhead. Pikeminnow are common in these channels. Standing crop of benthic algae and cyanobacteria are visible and even dominant in these channels, especially in summer months. Potential for deep pools and connections to larger floodplains. In channel restoration potential is limited relative to tributaries, and restoration activities will typically be larger and process-based.
1,000–10,0000	Large Mainstem	Used for seasonal rearing, adult staging. and migration, primary spawning for Green Sturgeon and significant spawning for Chinook Salmon and Pacific Lamprey. Riparian shading is limited or non-existent. In channel restoration potential limited relative to tributaries and mainstems, but may be a focus area of reconnecting floodplains.

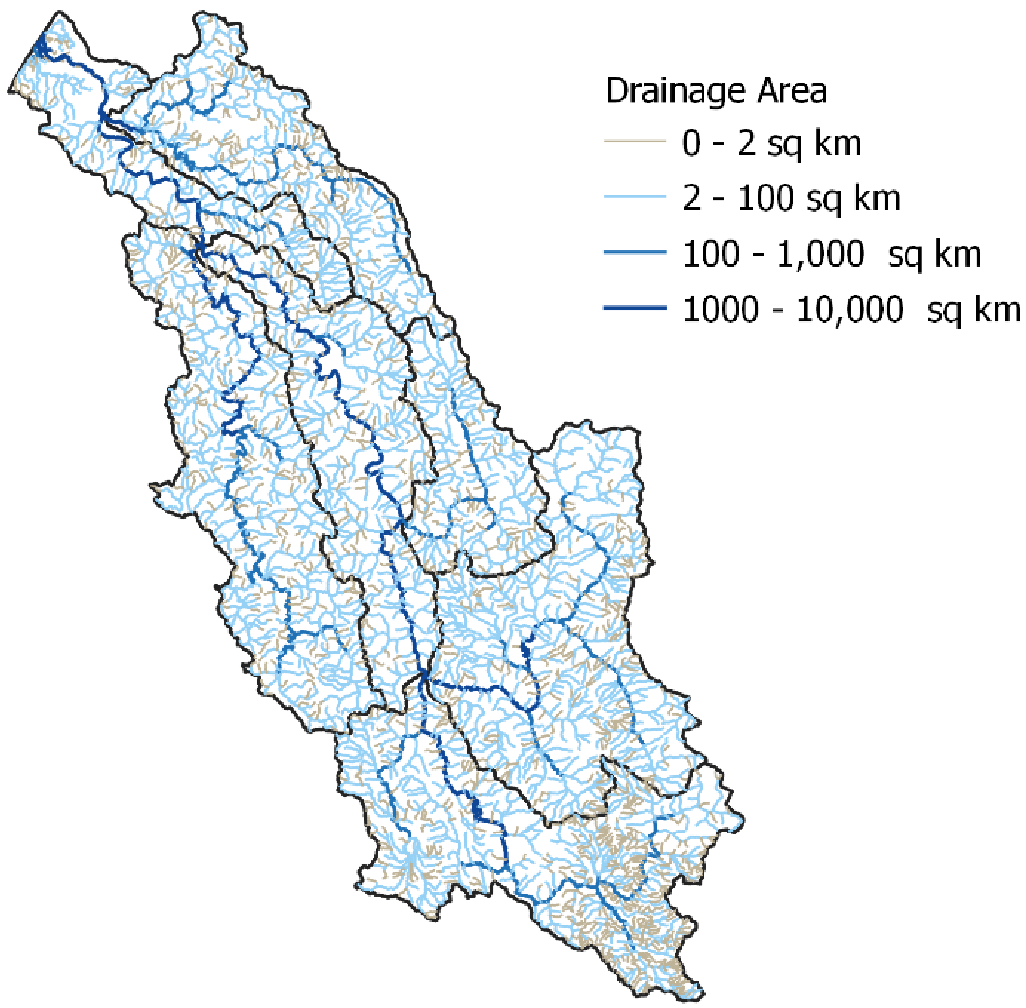

Figure C-1. Streams within each drainage area category in the Eel River (see Table C-3).

2.4 Slope

Slope categories were selected primarily based on predicted differences in use by salmonids (Stillwater Sciences 2013, Burnett et al 2007), and previous studies that have used slope to estimate parr capacity for salmonid species in the Eel River (FitzGerald et al. 2022, Cooper et al 2020). Selected slope categories are described in Table C-4. The larger drainage areas, Mainstems and Large Mainstems, are dominated by low slopes (<1%), while all the very high gradient channels (>12%) occur in tributaries and small tributaries (Figure C-2 and Figure C-3). For both Mainstems and Large Mainstems, the vast majority of channel segments fell within the less than 2% category, so we did not divide these drainage area groups by slope. While Small Tributaries are important sources of water and sediment, they are expected to provide relatively little fish habitat due to their small size, regardless of slope. For this reason, all slope categories within Small Tributaries were grouped together. The Tributary category was divided into all four slope groups.

Table C-4. Slope breaks that were considered in developing channel archetypes.

Slope break	Category	Description
<2%	Low gradient	Ideal habitat for Chinook and Coho, potential use by steelhead. Strong Coho streams (Hollow Tree Creek, Indian Creek) are less than 2% gradient
2–7%	Medium gradient	Potential habitat for Coho, ideal habitat for steelhead. Coho are more common at the lower end of this slope group (i.e., up to 5%; Burnett et al 2007)
7–12%	High gradient	Likely used by steelhead, possible in-channel restoration actions are limited
>12%	Very high gradient	Likely not productive fish habitat

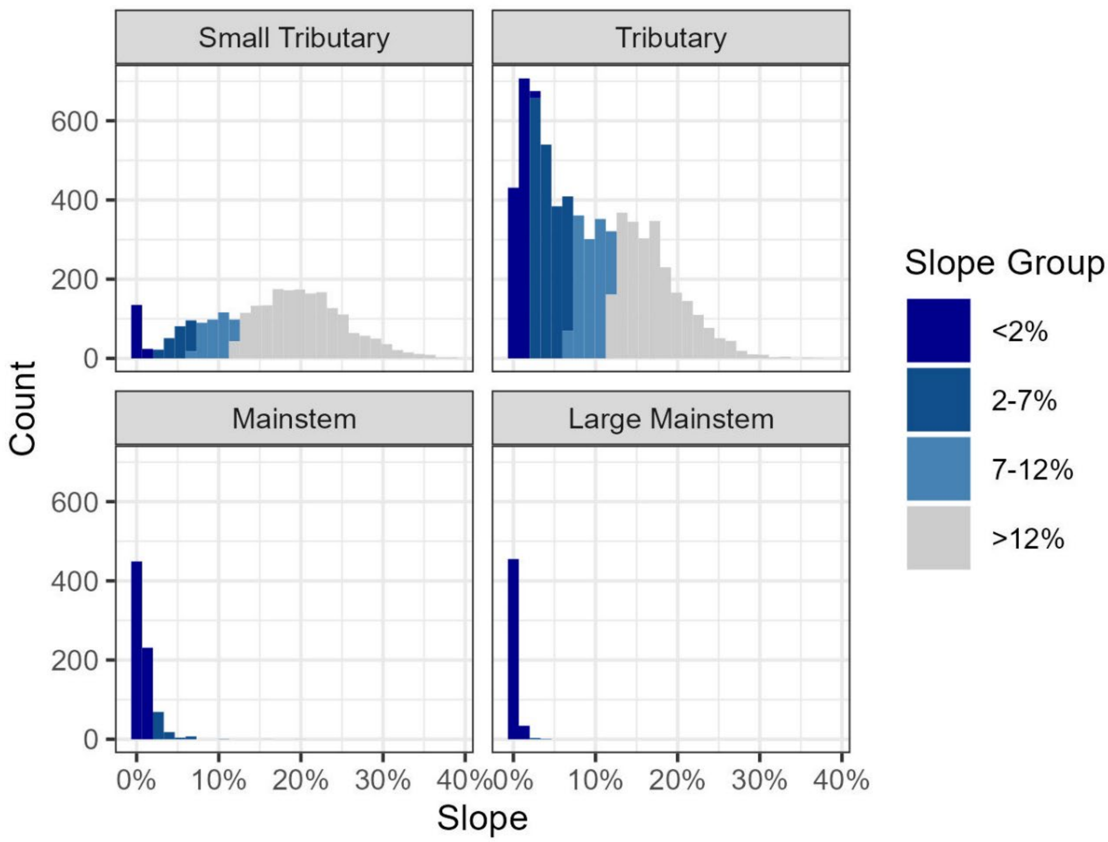

Figure C-2. The distribution of channel segments in each slope category within the drainage area categories, colored by the slope categories considered.

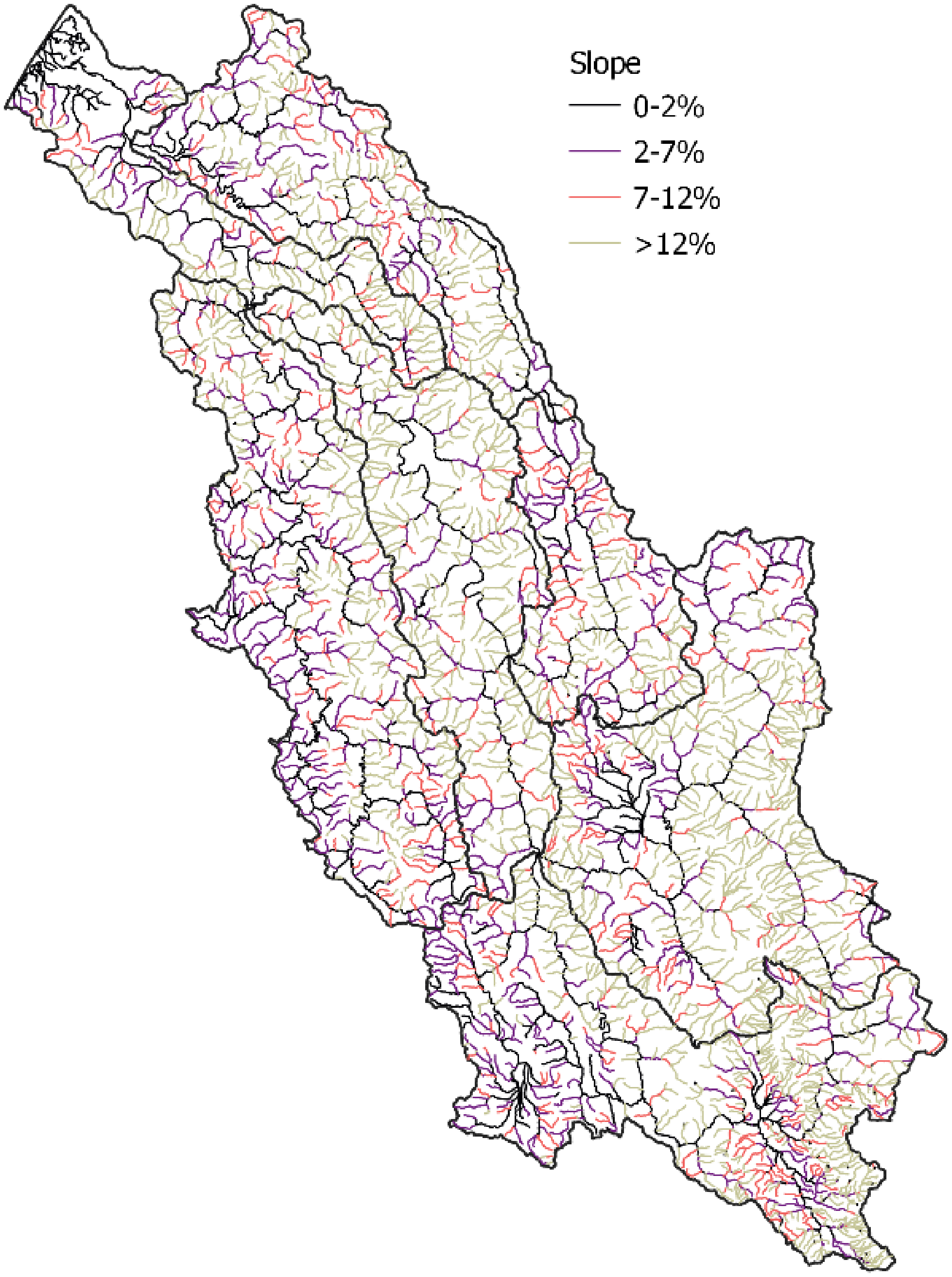

Figure C-3. Map of slope breaks at the stream reach scale in the Eel River.

2.5 Water Temperature

Water temperature categories were developed based in part on (1) reported thermal tolerances of salmonid species (Myrick and Cech 2001, North Coast Regional Water Quality Control Board 2010, FitzGerald et al. 2021), (2) field observations of when steelhead move into thermal refugia in the Eel River (Wang et al. 2020) and the Klamath River (Sutton et al. 2007, Brewitt and Danner 2014), (3) temperatures at which steelhead are infected with parasites in the Eel River (Schaaf et al 2017), and (4) temperatures at which nonnative Sacramento Pikeminnow become competitively dominant over steelhead (Reese and Harvey 2002). Selected temperature categories are listed and described in Table C-5. Since the water temperature dataset used is based on predicted monthly mean temperature for each channel segment, for reference, we provided the MWAT that is equivalent to August mean temperatures, based on a regression between the two metrics from watershed-wide empirical data (Asarian et al. 2016) ($r^2 = 0.94$, Mean Monthly = 0.864 * MWAT + 1.0035, n = 880 observations).

While we used temperatures in August to develop groups of streams with similar dry season thermal characteristics, it is important to note that many of the channels that fall into the “seasonally unsuitable” or “stressful” category may have high value for juvenile salmonid feeding and growth, especially if fish can move or find thermal refugia in the days/times when temperatures are too warm. Both these marginal and seasonally uninhabitable streams likely play a large role in providing high-growth opportunities for salmonids during cooler periods like spring and fall (Armstrong et al. 2022). Furthermore, the source of these data is a large-scale multivariate temperature model, that does not identify and integrate small-scale thermal refugia (e.g., tributary confluences, deep stratified pools).

Table C-5. Temperature categories for mean monthly temperature to group streams of similar thermal conditions.

Category	August Mean Temperature (°C)	Equivalent MWAT (°C)	Description
Cold	<17	<18	Ideal for Coho, steelhead, and Chinook rearing throughout the summer, may be lower growth in winter/spring
Cool	17–20	18–22	High-growth conditions for steelhead, likely tolerable by Coho earlier in the spring/summer, likely used by Chinook before emigration
Warm	20–24	22–26	Suitable for steelhead and Chinook rearing, especially with high food and/or access to thermal refugia
Hot	>24	>26	Only seasonal rearing for steelhead, higher probability of parasites/diseases

We next plotted the distribution of mean August temperatures for the drainage area categories (Figure C-4). The majority of Large Mainstems fell within the 20–24°C category, so we continued to treat Large Mainstems as one archetype. The only channel segments that fell within the >24°C category were Large Mainstems, and these can be separately identified. The Mainstems contained channels that were between <20°C and >20°C, and we divided these channels into Cool and Warm Mainstems, respectively. Small tributaries were dominated by channels that were <17°C and are not critical to fish habitat regardless of thermal conditions, so we continue to treat them as one archetype.

For the Tributary groups, we predicted that there would be patterns in mean August temperature related to the slope breaks, so we plotted the number of channels in each water temperature × slope group (Figure C-5 and Figure C-6). The low (<2%) and medium (2–7%) slope groups contained channels from three water temperature groups, <17°C, 17–20°C, and 20–24°C. For both slope groups, we maintained these “Cold,” “Cool,” and “Warm” groupings. The high (7–12%) slope group was dominated by channels that were either <17°C or 17–20°C, and so we categorized these channels as either “Cold,” or “Cool,” respectively. The very high slope group (>12%) was dominated by channels that were < 17°C. Given that these channels will likely only be used by steelhead, and likely not a priority for restoration, we do not consider separate thermal groups.

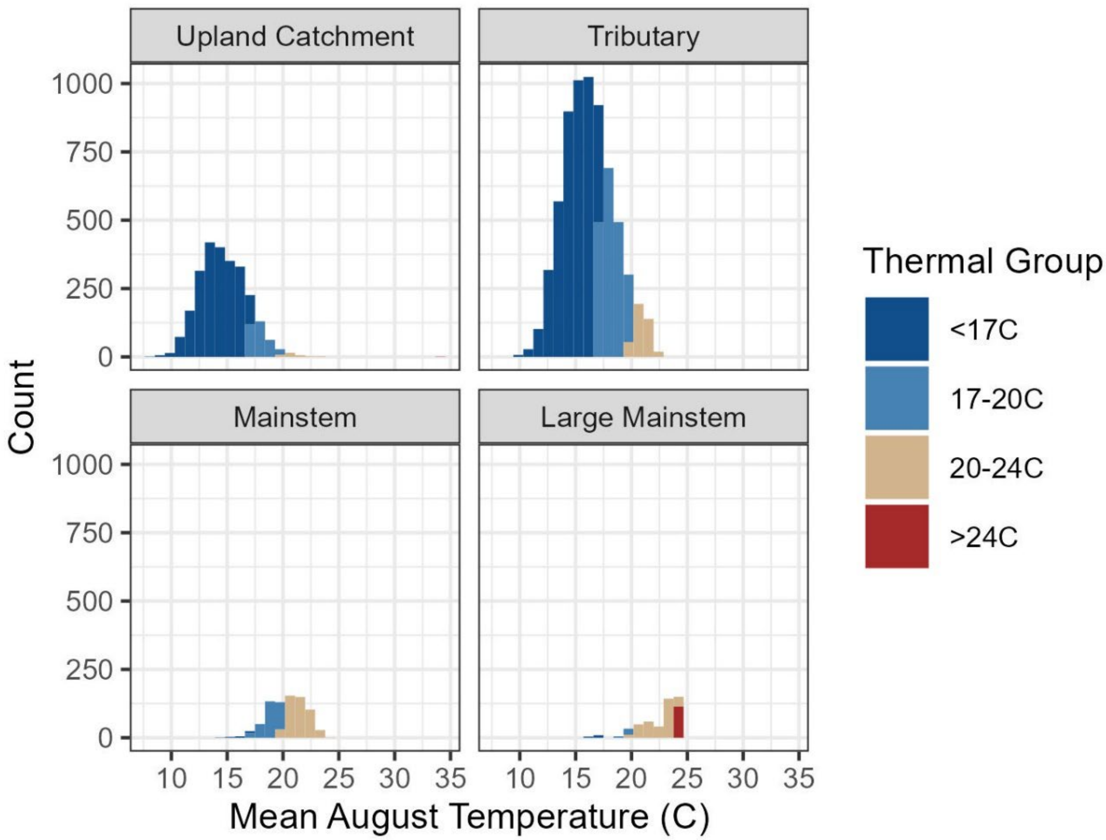

Figure C-4. Distribution of channel segments by mean August water temperature category within the drainage area categories

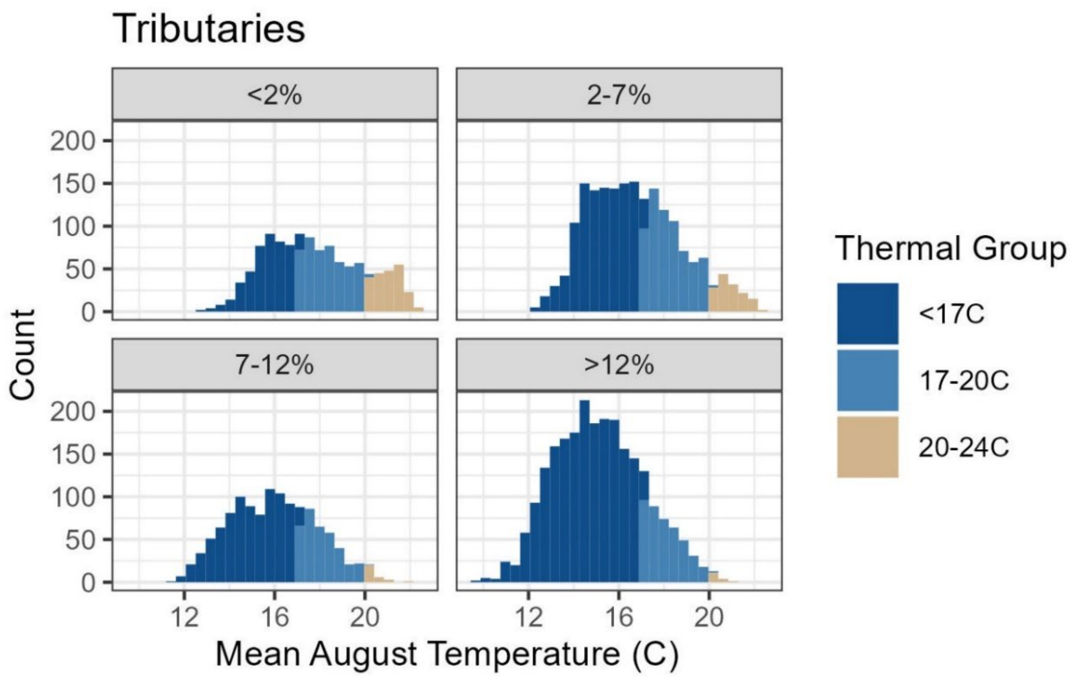

Figure C-5. Distribution of mean August water temperatures within the slope groups of Tributary streams (2–100 km^2).

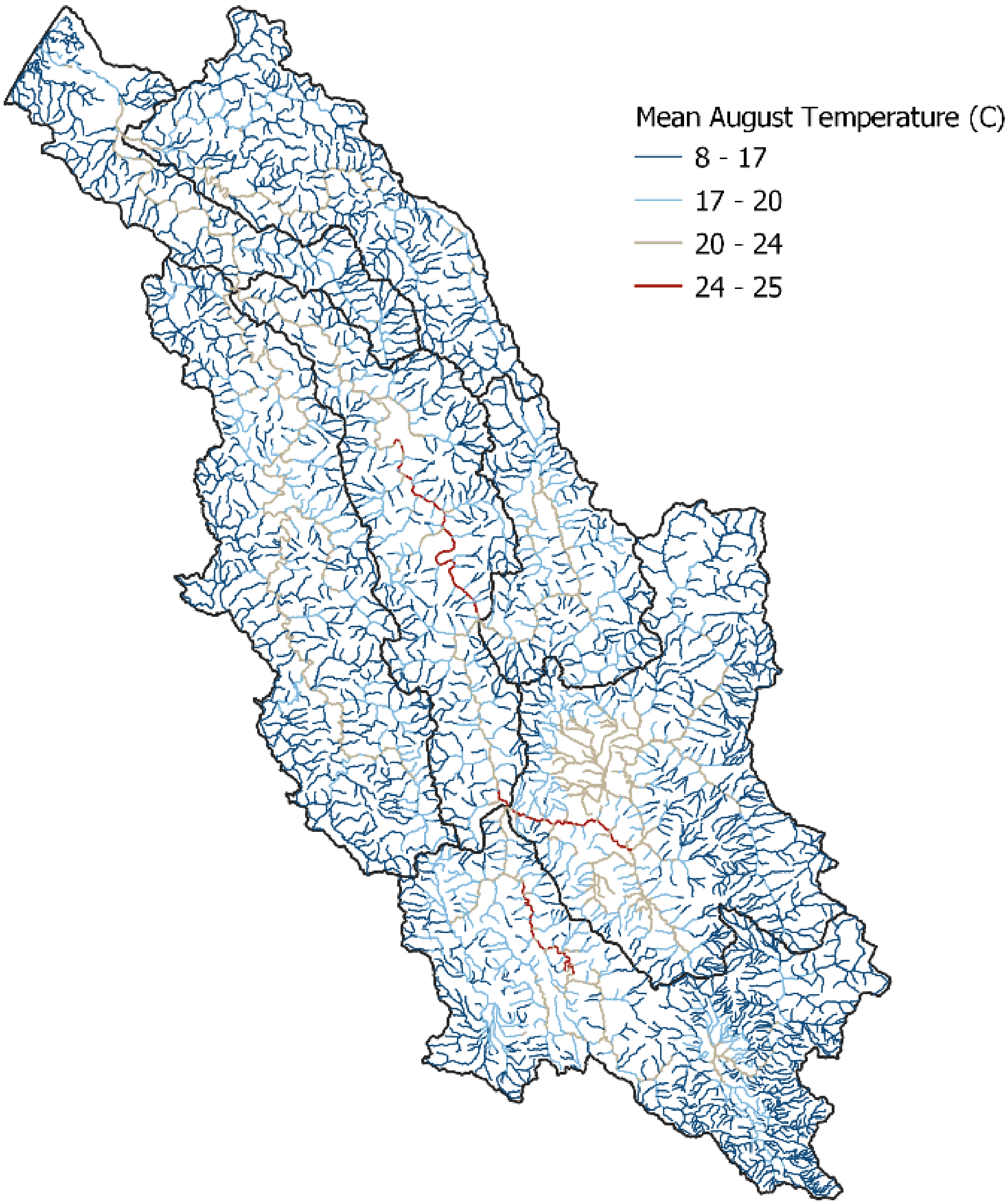

Figure C-6. Mean August water temperatures groups in the Eel River.

3 RESULTS

Our grouping analysis with drainage area, slope, and water temperatures led to 14 channel archetype groups with the addition of the Estuary ecotone (Table C-6). Each of these channel archetypes incorporate substantial habitat diversity. However, they also encompass information on potential use by salmonid species, particularly for natal rearing, non-natal rearing, and migration pathways (Table C-7). Preliminary predicted use of channel archetypes by focal species for spawning and natal rearing (NR), non-natal rearing (NNR), rearing (R), and migration (M) (Figure C-7), as well as large categories of restoration actions that might be considered, for example riparian planting, in-channel wood addition, vs. upslope management and large-scale channel restoration (e.g., floodplain reconnection, pool dredging) (refer to Task 3).

Table C-6. List of channel archetypes and the encompassing drainage area, slope, and thermal groups. The range of mean May and August temperatures is shown to highlight that cool and warm channel archetypes can be seasonally suitable, and even more optimal, for salmonid growth.

Channel archetype	Code	Drainage area category	Slope category	Thermal category	Mean August temperature range (°C)	Mean May temperature range (°C)
Small tributary	0	Small tributary (<2 km2)	All	Cold, Cool, Warm	8.3–23.3	6.5–21.2
Low gradient, cold tributary	1.1-cold	Tributary ($2–100\ km^2$)	<2%	Cold	11.5–17.0	8.9–15.4
Low gradient, cool tributary	1.1-cool			Cool	17.0–20.0	9.7–16.4
Low gradient, warm tributary	1.1-warm			Warm	20.0–23.3	11.4–16.5
Mid gradient, cold tributary	1.2-cold		2–7%	Cold	11.6–17.0	7.4–15.3
Mid gradient, cool tributary	1.2-cool			Cool	17.0–20.0	9.3–16.6
Mid gradient, warm tributary	1.2-warm			Warm	20.0–22.3	12.3–15.3
High gradient, cold tributary	1.3-cold		7–12%	Cold	10.4–17.0	7.5–15.2
High gradient, cool tributary	1.3-cool			Cool. Warm,	17.0–21.8	10.5–15.5
Very high gradient tributary	1.4		>12%	Cold, Cool, Warm	8.3–20.9	6.8–14.9
Cool mainstem	2-cool	Mainstem ($100–1,000\ km^2$)	<2%, 2–7%	Cool	14.7–20	9.7–15.9
Warm mainstem	2-warm		<2%, 2–7%	Warm	20–23.8	10.6–16.6
Large mainstem	3	Large mainstem ($>1,000\ km^2$)	<2%	Cold, Cool, Warm, Hot	16.2–24.6	12.4–16.1
Estuary	4	Estuary	<1%	-	-	-

Table C-1. Preliminary predicted use of channel archetypes by focal species for spawning and natal rearing (NR), non-natal rearing (NNR),rearing (R), and migration (M).

Channel archetype	Chinook				Coho				Steelhead				Green Sturgeon	Pacific Lamprey	Sacramento Pikeminnow
	NR	NNR Wet	NNR Dry	M	NR	NNR Wet	NNR Dry	M	NR	NNR Wet	NNR Dry	M	M & R	M & R	
Small tributary		P				Y			P	P	P				
Low gradient, cold tributary	Y	Y	Y		Y	Y	Y		Y	Y	Y			Y	P
Low gradient, cool tributary	Y	Y	Y		Y	Y	P		Y	Y	Y			Y	Y
Low gradient, warm tributary	Y	P			P	Y			Y	Y	Y			Y	Y
Mid gradient, cold tributary	Y	P	P		Y	P	Y		Y	Y	Y			Y	P
Mid gradient, cool tributary	Y	P			Y	P	P		Y	Y	Y			Y	Y
Mid gradient, warm tributary	P	P			Y	P			Y	Y	Y			Y	Y
High gradient, cold tributary									Y	P	Y				
High gradient, cool tributary									Y	P	Y				
Very high gradient tributary											P				
Cool mainstem	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	Y	Y
Warm mainstem	Y	Y		Y	P	P		Y	Y	Y	Y	Y	P	Y	Y
Large mainstem	Y	Y		Y		P		Y		P	Y	Y	Y	Y	Y
Estuary		Y	Y	Y		Y	Y	Y		Y	Y	Y	Y	Y	Y

[1] Y = yes, commonly used, P = possible, or less-frequently used, and blank = not used.

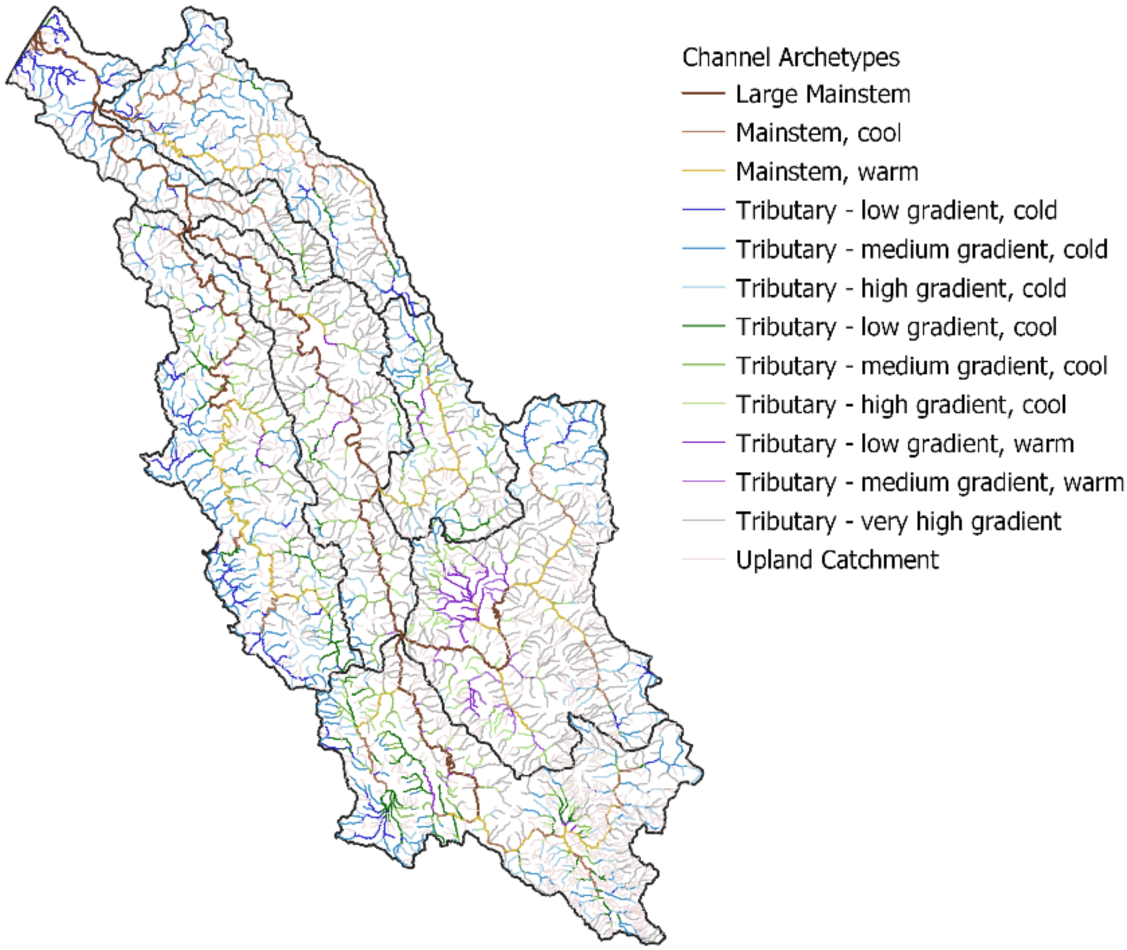

Figure C-7. Channel archetypes in the Eel River that arise from groupings by drainage area, gradient, and thermal regime.

4 ADDITIONAL DATA OVERLAYS

The channel archetypes provide a template that allows for the addition of other spatial datasets to understand ecological hotspots and unique geomorphic features. For example, valley confinement should be considered in the prioritization framework, especially when identifying habitats that may provide strong over-wintering habitat for Coho Salmon and steelhead. Similarly, trends in baseflows (drier versus wetter) can be considered across the Eel River and within sub-watersheds to highlight tributaries that are more likely to be intermittent or contribute disproportionately high volumes of cool water.

4.1 Baseflows

We scaled modeled dry season baseflows for the Eel River by drainage area for every stream segment to standardize the dataset relative to stream size. This scaling allows to analyze *relative* baseflows throughout the watershed, acknowledging that there is often error in the estimated magnitude of baseflows in the modelled functional flows (Grantham et al 2022). This dataset revealed large spatial patterns in baseflows throughout the watershed (Figure C-8). For example, the South Fork Eel River is dominated by channels that are wetter than average for their drainage area, while the Upper Main Eel and Middle Fork Eel sub-watersheds are drier than average. These patterns align with predictions that arise from the role of subsurface lithology in determining water storage and summer baseflows in the Eel River (Hahm et al 2019, Dralle et al 2023). Because the patterns in baseflow are driven by larger-scale geologic features, we decided not to include these groupings in our channel archetypes but note that these trends should be considered at a sub-watershed level. For example, warm, low gradients tributaries in the Middle Fork Eel River are much more likely to be seasonally dry than the same archetype in the South Fork Eel River.

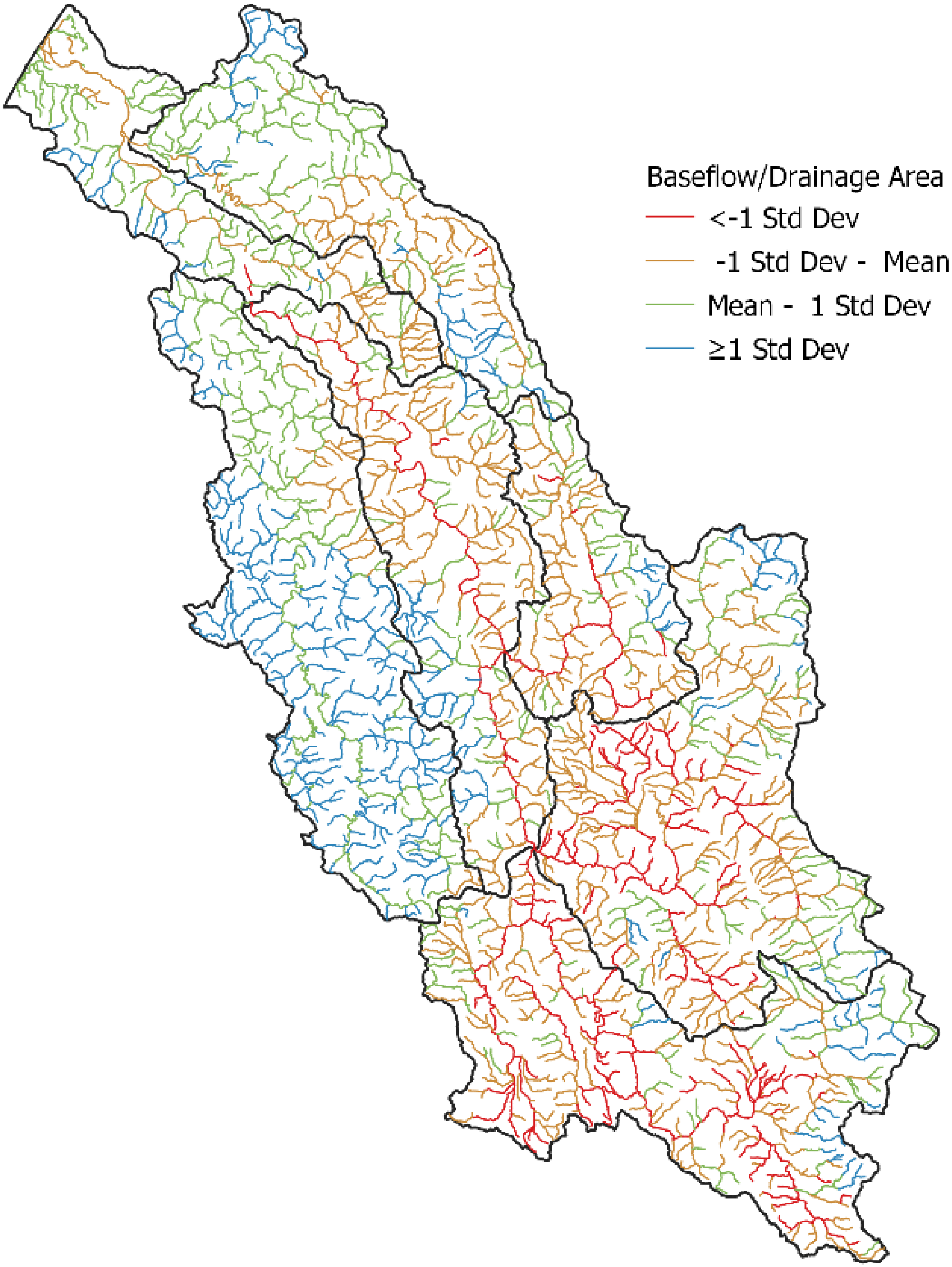

Figure C-8. Modeled dry season baseflows, standardized by drainage area, in the Eel River. Drainages <2 km^2 are omitted.

4.2 Valley Confinement

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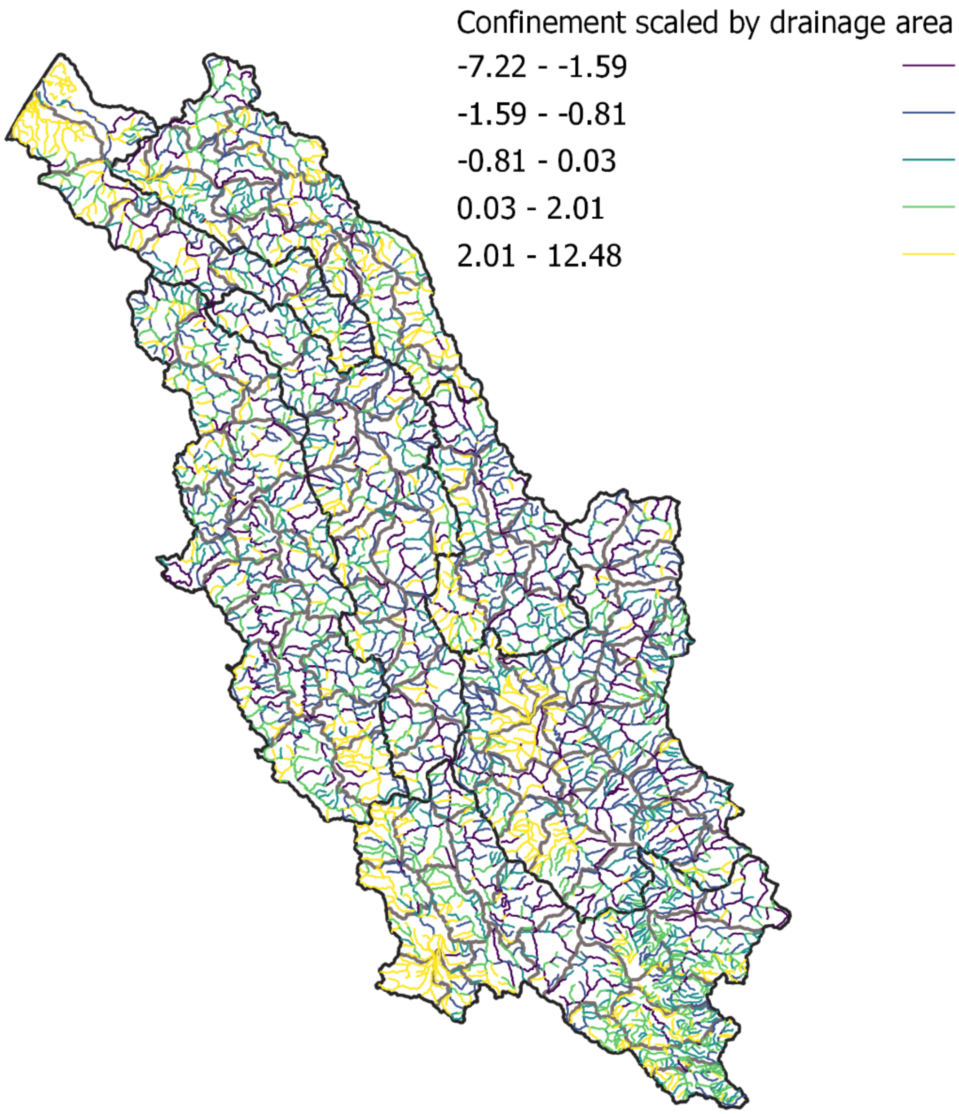

Figure C-9. Relative valley confinement (valley width scaled by drainage area) along the channel reaches in the Eel River watershed.

4.3 Geomorphic Channel Types

Channel types were estimated from slope and drainage area, so are redundant with these previous physical variables. We show the distribution of predicted channel types within our drainage area and slope categories to support our grouping analysis based on those variables (Figure C-10). Large mainstems and mainstems are primarily low-gradient and plane-bed channels. Cascades, step-pool habitats are primarily found in Tributaries, with cascades being most common in the >12% slope group. While these geomorphic channel classification predictions were not used in the channel archetype groupings, they may be helpful in identifying habitat features of interest within an archetype.

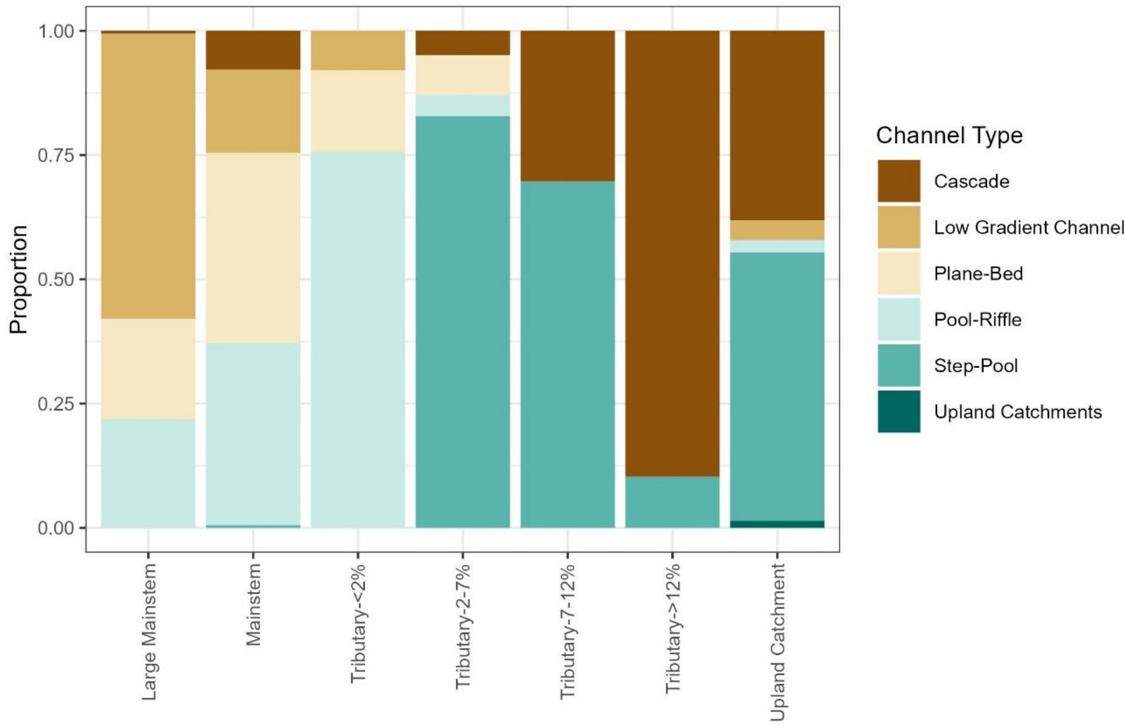

Figure C-10. Predicted geomorphic channel types within the drainage area and slope groupings.

5 NEXT STEPS

One next step in spatial analyses that will guide restoration planning is characterization of current channel condition, relative to historic or predicted condition. For example, many large mainstems historically had deep pools that were suitable holding habitat for migrating fish, but these have been filled in from unnaturally high sediment loads. Similarly, tributary habitats are predicted to have riparian areas that contribute allochthonous carbon and buffer stream temperatures. Identifying geographic areas that currently lack a riparian forest, due to forest fires or drought, along with channel types that are most in need of temperature mitigation, will guide prioritization. In summary, next steps in the Eel River Restoration Program will characterize differences between the predicted/historic and current channel condition.

Another next step is to consider classifying the diversity of estuary habitats. It is currently included as its own channel archetype in this analysis, given its homogeneity in drainage area and slope, and the lack of temperature data at a fine enough resolution to capture thermal diversity used here. When identification of restoration action and fish use *within* the estuary is approached, conducting a classification similar to Simenstad et al. (2011) will be helpful.

6 PLOTS OF CHANNEL ARCHETYPES BY SUBWATERSHEDS AND HUC 12 UNITS

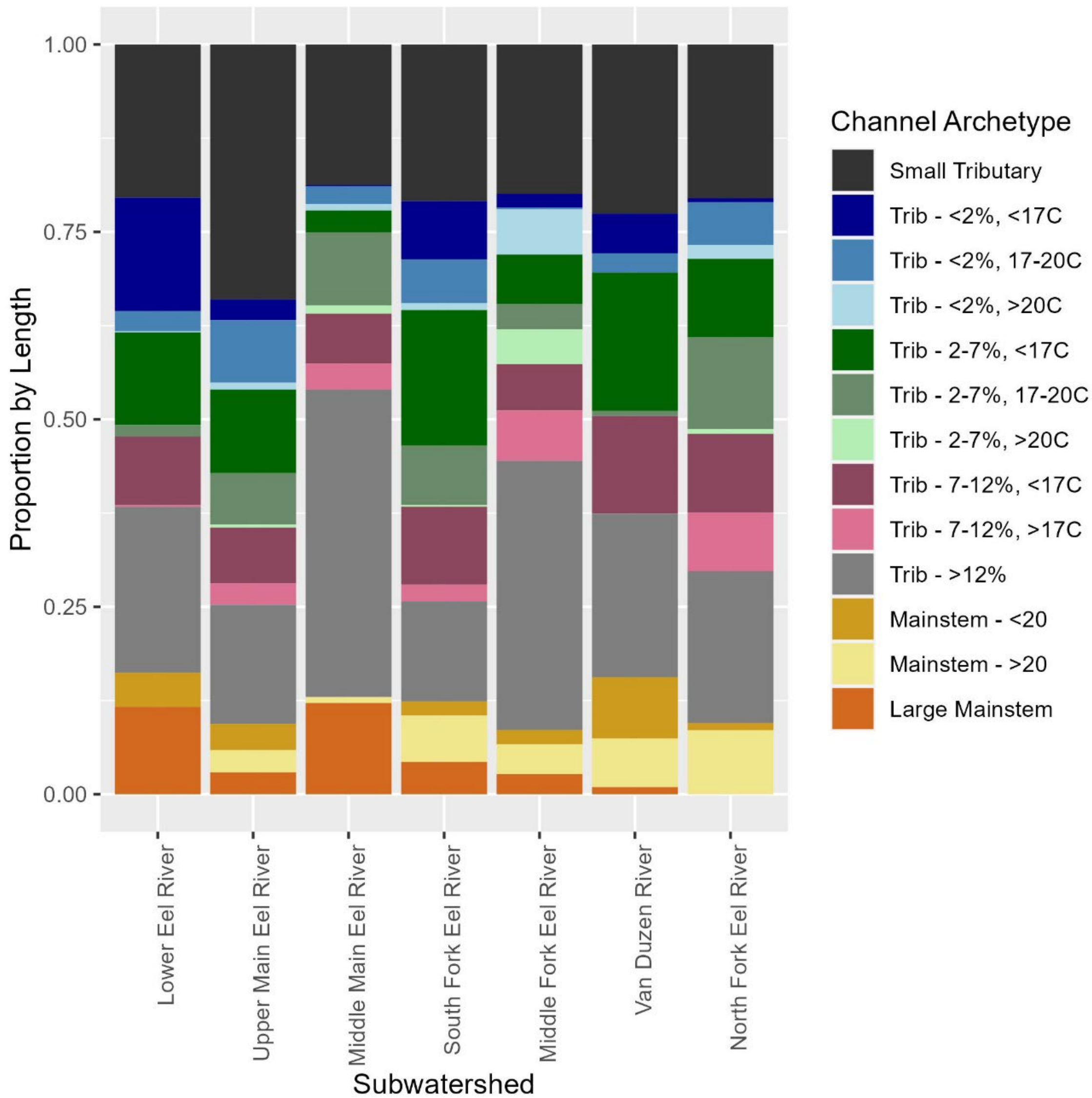

Figure C-11. Proportion of channel length that falls into each channel archetype group within the seven sub-watersheds, excluding the estuary.

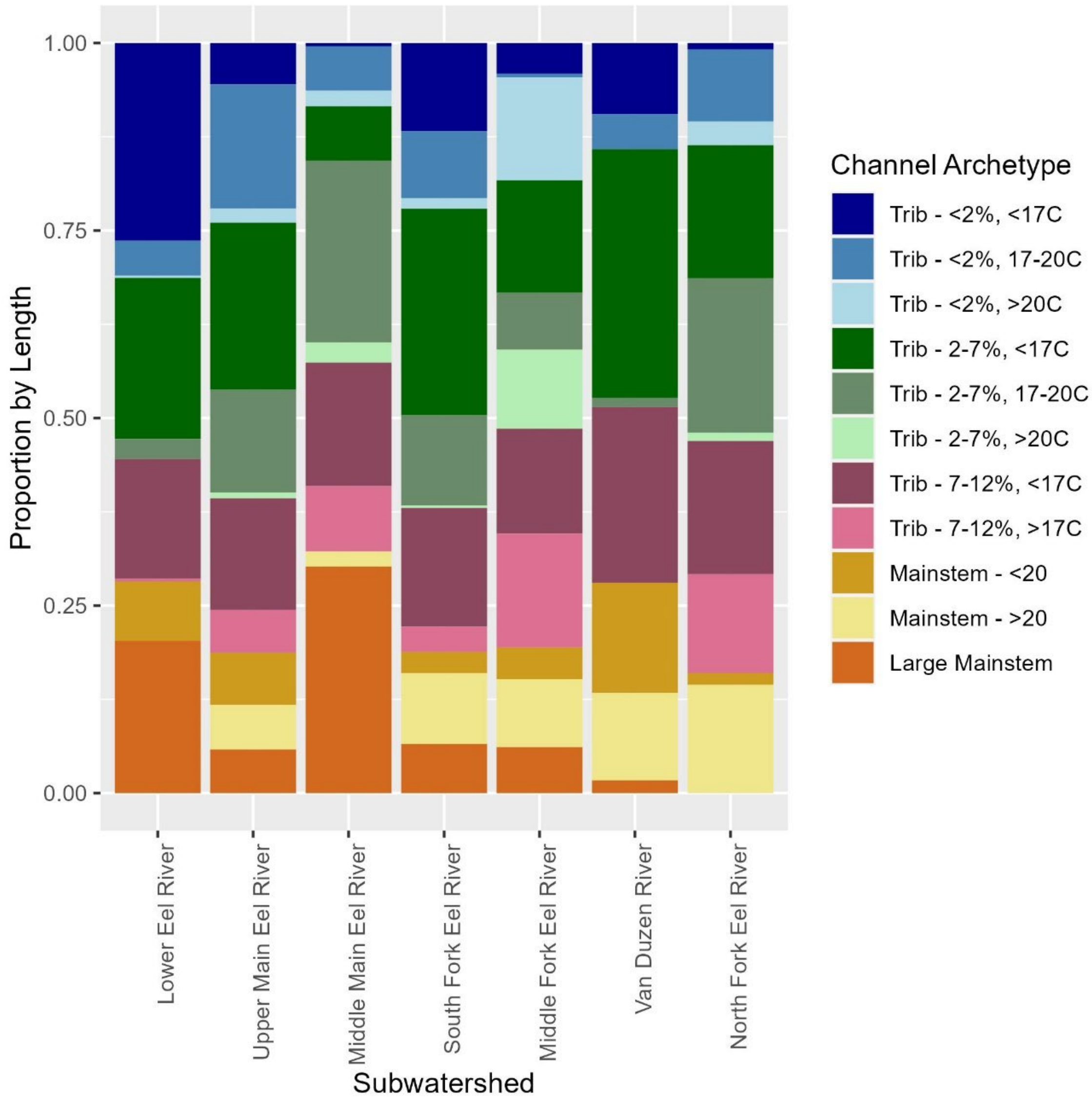

Figure C-12. Proportion of channel length that falls into each channel archetype group within the seven sub-watersheds, excluding Small Tributaries, Tributaries with >12% slope, and the estuary.

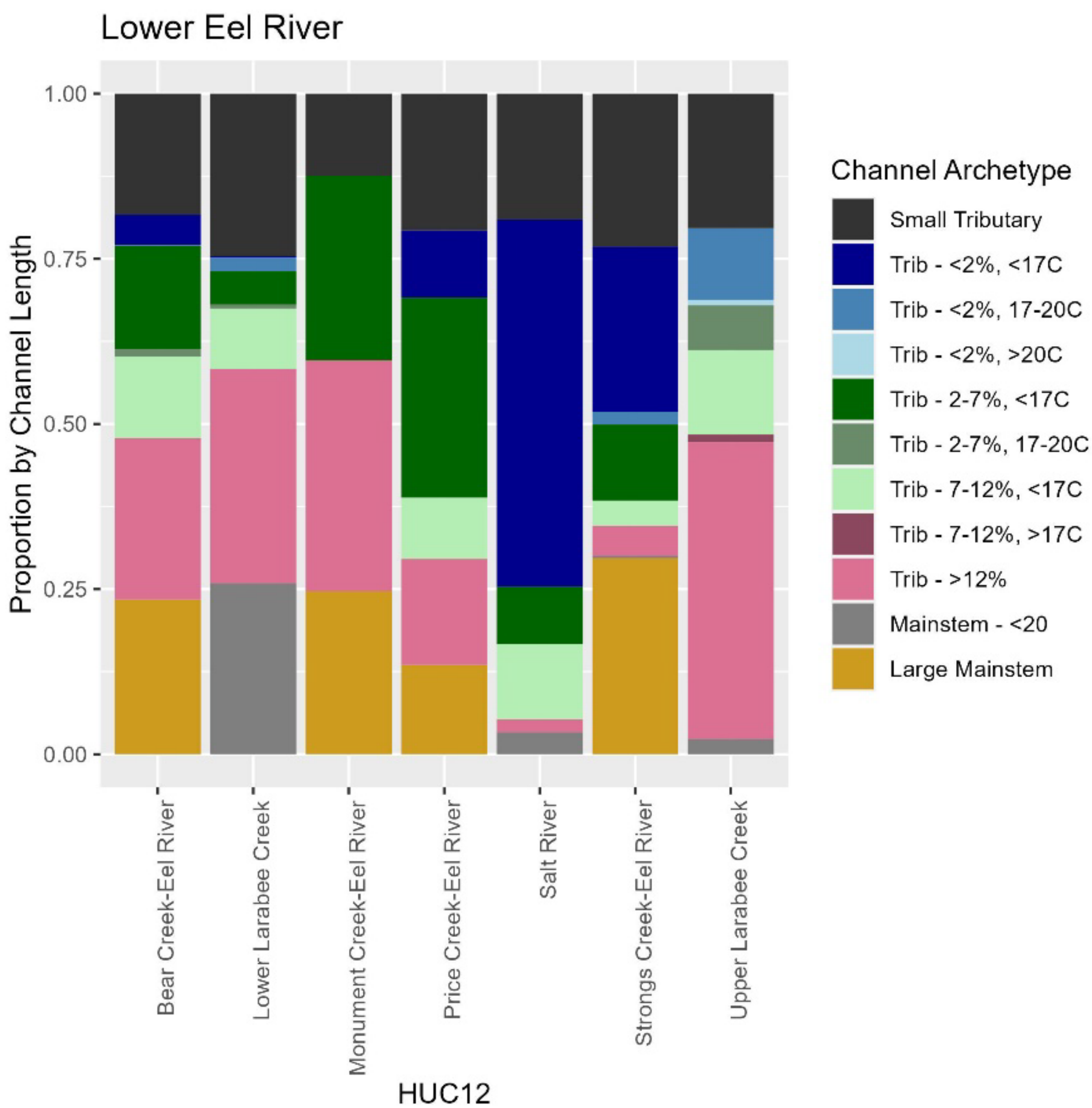

Figure C-13. Proportion of channel archetypes by length within each HUC-12 sub-basin in the Lower Eel River sub-watershed.

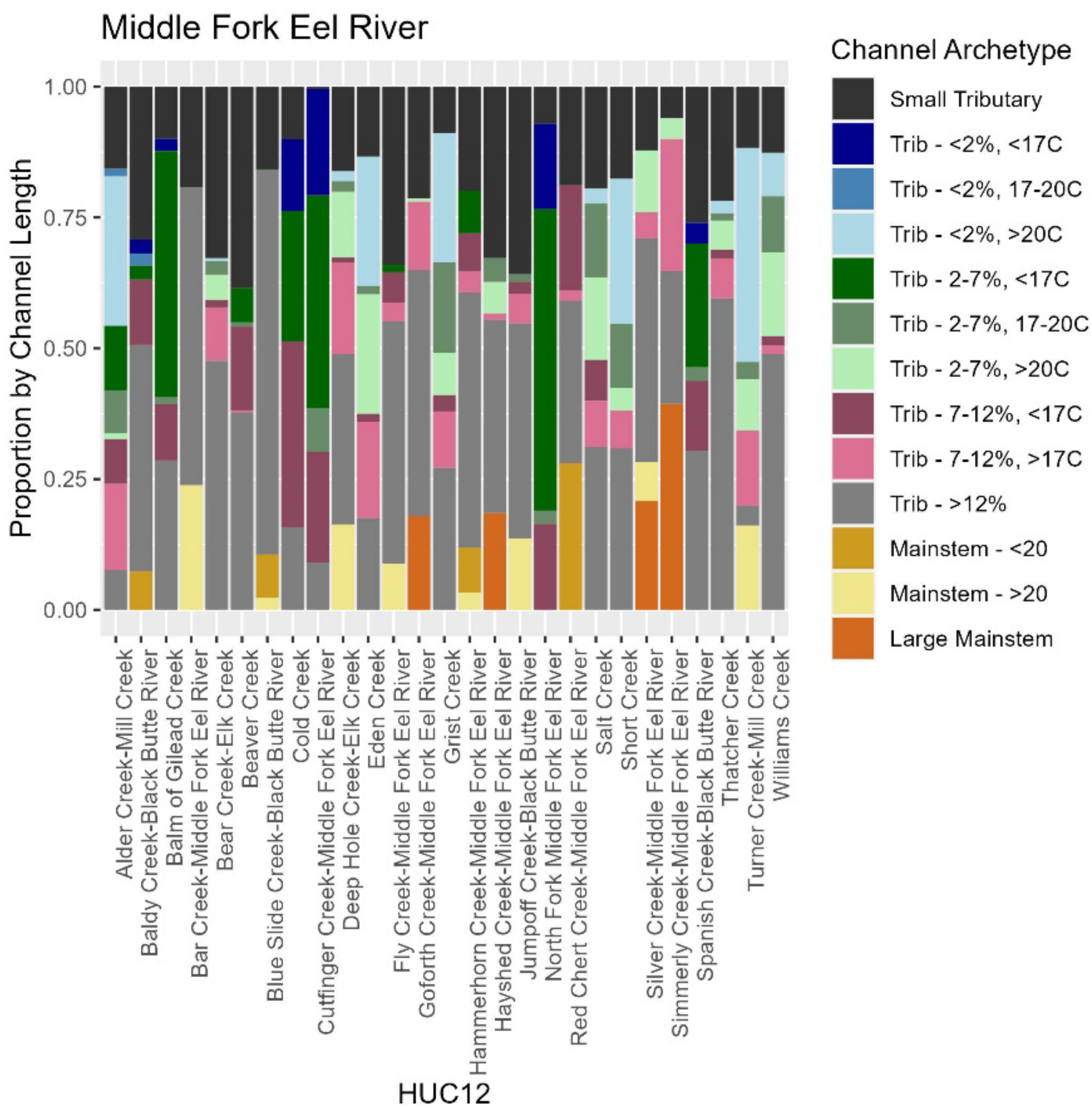

Figure C-14. Proportion of channel archetypes by length within each HUC-12 sub-basin in the Middle Fork Eel River sub-watershed.

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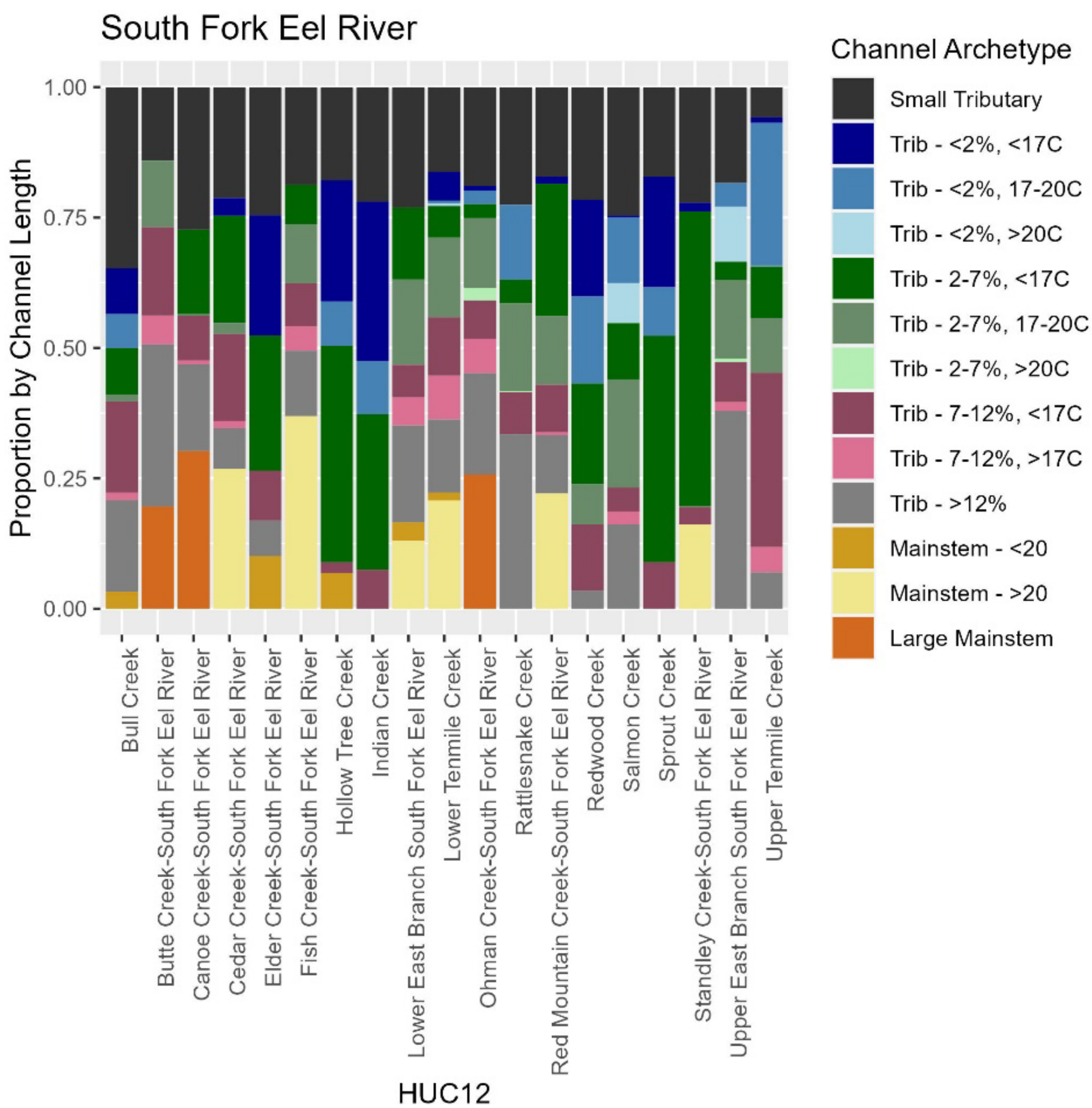

Figure C-15. Proportion of channel archetypes by length within each HUC-12 sub-basin in the Lower Eel River sub-watershed.

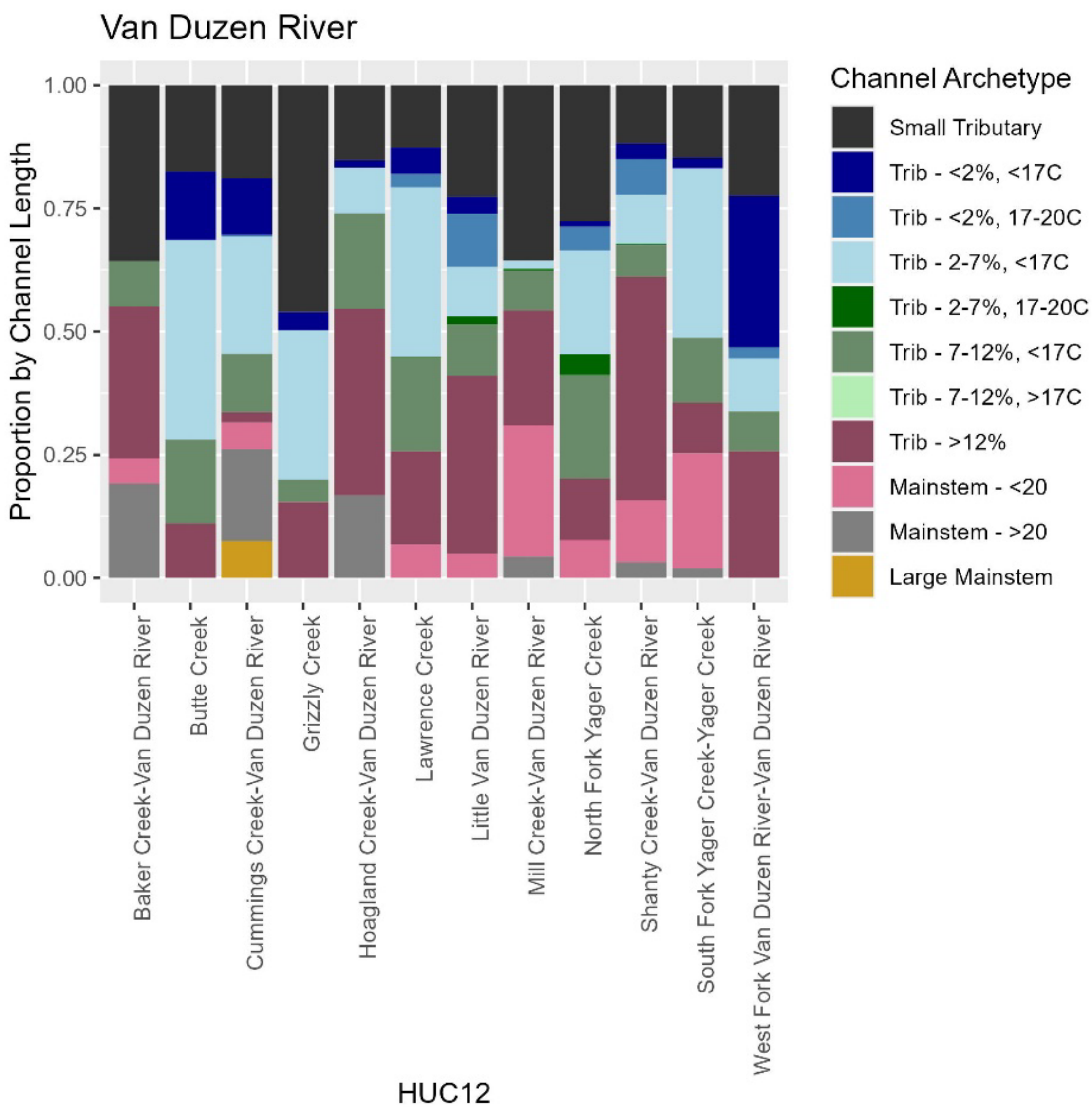

Figure C-16. Proportion of channel archetypes by length within each HUC-12 sub-basin in the Van Duzen River River sub-watershed.

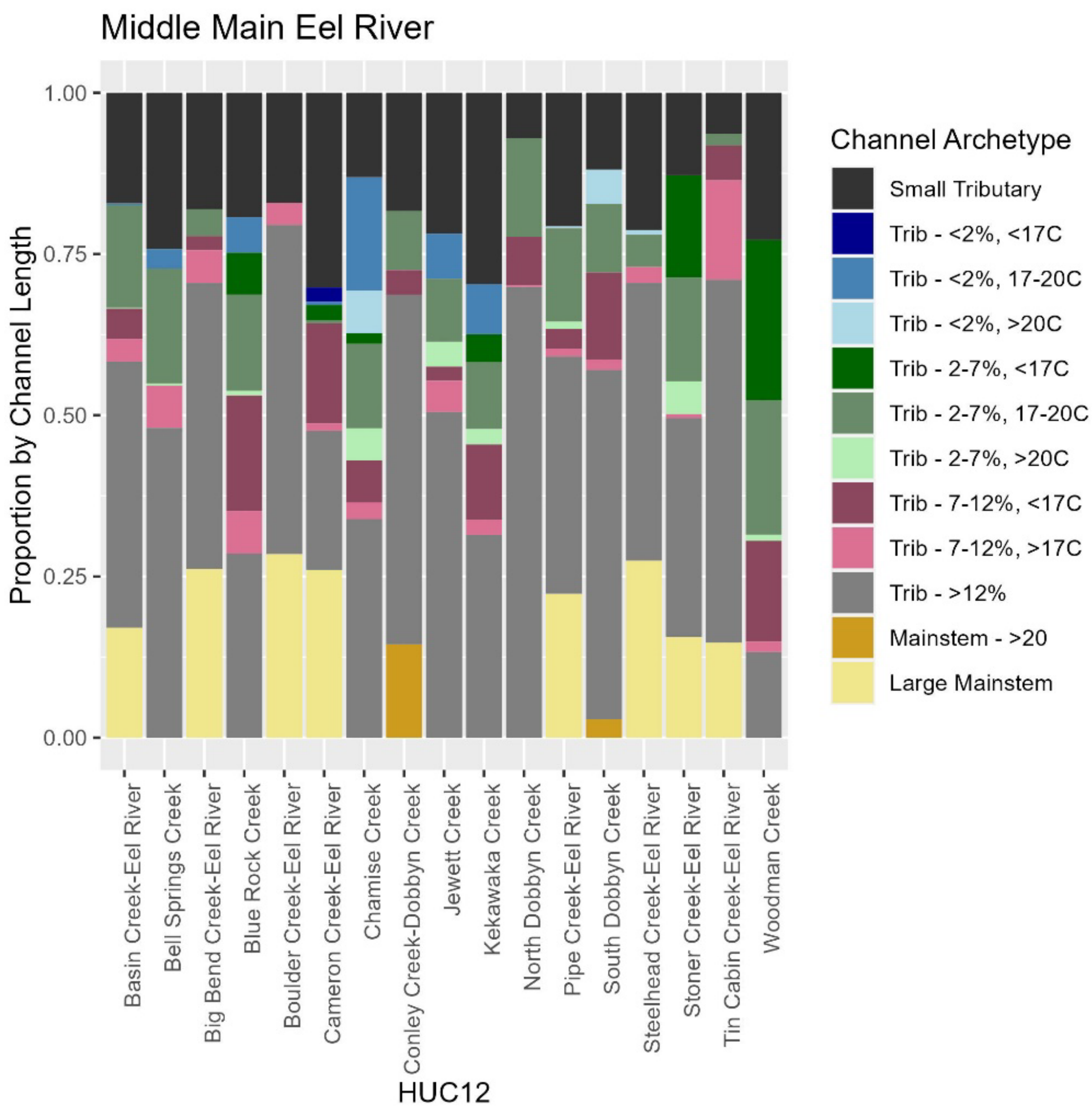

Figure C-17. Proportion of channel archetypes by length within each HUC-12 sub-basin in the Middle Main Eel River sub-watershed.

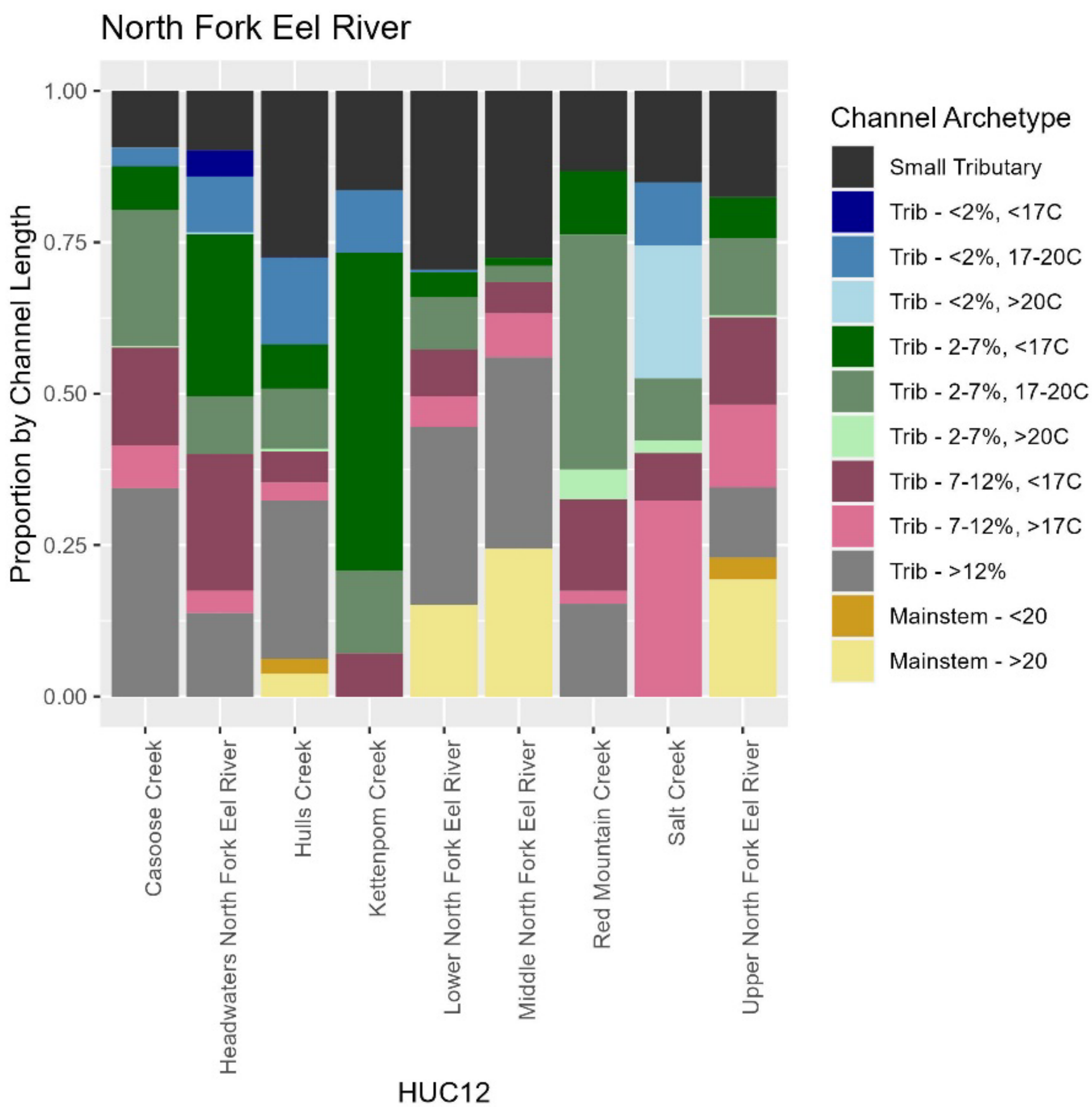

Figure C-18. Proportion of channel archetypes by length within each HUC-12 sub-basin in the North Fork Eel River sub-watershed.

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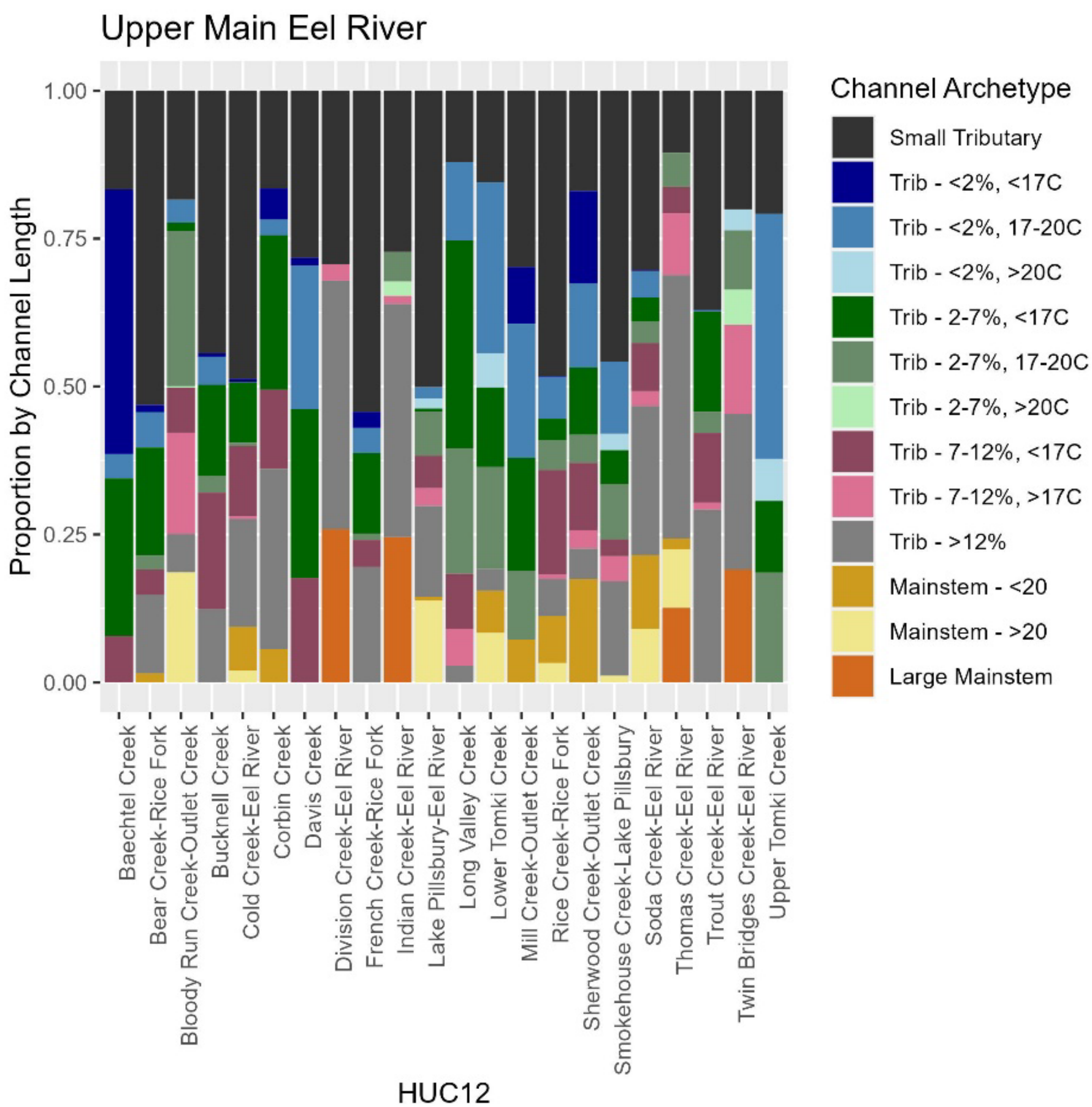

Figure C-19. Proportion of channel archetypes by length within each HUC-12 sub-basin in the Upper Main Eel River sub-watershed.

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Appendix D

Species Descriptions and Life-History Conceptual Models

NOTES FOR REVIEWERS:

This draft appendix is an in-process work product that is incomplete and has not undergone final editorial review and formatting.

This draft currently includes working versions of Coho Salmon and steelhead conceptual models to allow readers to understand the organization and content that will be included in the appendix of the Final Plan. Subsections of the Coho Salmon and steelhead conceptual models that are in process or not included are noted in blue text.

Chinook Salmon, Pacific Lamprey, and Green Sturgeon species descriptions and conceptual models are in process and will be provided in the Final Plan in June.

The overall approach, rationale for, and uses of these life-history conceptual models in the context of the Eel River Restoration and Conservation Program are described in Section 3 of the Plan.

The report authors request that reviewers who comment on this appendix focus on the approach, organization, content, and corrections of the two included species to guide us in completing the conceptual models for the final appendix.

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1 CHINOOK SALMON – TO BE PROVIDED FOR FINAL

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1.2 Distribution

1.3 Ecology, Life-history, and Habitat Needs

1.4 Life-history Diversity Conceptual Model

1.5 Conceptual Model Outcomes

1.6 References (Chinook Salmon)

2 COHO SALMON

2.1 Population Status

Coho Salmon in the Eel River watershed are listed as threatened under both the California and federal endangered species acts (CESA and ESA) (CDFG 2002, NMFS 2014). Populations in the Eel River are part of the federally threatened Southern Oregon/Northern California Coast (SONCC) Evolutionary Significant Unit (ESU), which includes all naturally spawning populations between Punta Gorda, California, and Cape Blanco, Oregon (NMFS 2014). Within the Eel River, Williams et al. (2006) identified seven "population units" based on historical distribution, geographic isolation, genetic data, population dynamics, habitat availability, environmental characteristics, and other factors. These population units, which are addressed separately in the species recovery plan (NMFS 2014), include the Lower Eel/Van Duzen (downstream of South Fork Eel confluence), South Fork Eel, Mainstem Eel (South Fork confluence upstream to Middle Fork confluence), North Fork Eel, Middle Fork Eel, Middle Mainstem Eel (Middle Fork confluence up to and including Tomki Creek), and upper Mainstem Eel River (upstream of Tomki Creek). The South Fork Eel River, Lower Eel and Van Duzen River, and Middle Mainstem Eel River populations are classified as "*Core, Functionally Independent*" populations, which include *"…those with a high likelihood of persisting in isolation over a 100-year time scale and are not substantially altered by exchanges of individuals with other populations*." The Mainstem, North Fork, Middle Fork, and Upper Mainstem Eel River populations are all classified as "*Non-Core 2, Potentially Independent*" populations, which are those that "*…have a high likelihood of persisting in isolation over a 100-year time scale, but are too strongly influenced by immigration from other populations to exhibit independent dynamics."* Importantly, these classifications are based on expected historical population structure and characteristics. As described below, Coho Salmon populations are either extirpated or very rare in the Eel River watershed outside of the South Fork Eel, Lower Eel, and Van Duzen Rivers.

Available evidence suggests that abundance of Coho Salmon in northern California and the Eel River watershed has declined substantially relative to historical levels (Brown et al. 1994, Yoshiyama and Moyle 2010, CDFW 2014, NMFS 2014, Eel River Forum 2016). Yoshiyama and Moyle (2010) estimated that there were historically between 50,000 and 100,000 spawning adults in the watershed. Today, most spawning occurs in the South Fork Eel River and its tributaries, with relatively small numbers of fish spawning in tributaries to the lower Eel and Van Duzen rivers (NMFS 2014). Remnant numbers of Coho Salmon may occur in cooler tributaries in the watershed upstream of the South Fork in some years (NMFS 2014).

Historical counts of adults passing Benbow Dam on the mainstem South Fork Eel River in the late 1930s and 1940s, when the population was already depressed from overfishing, ranged from about 7,000–25,000 individuals (Stillwater Sciences 2022). These counts did not include fish that returned to the numerous tributaries downstream of the dam site (approximately one-third of the watershed). More recently, the Coho Salmon spawning population in the South Fork Eel River has ranged from about 350–5,000 individuals, based on redd estimates from 2010–2020 (Guczek et al. 2020) and assuming 2.5 adults per redd (South Fork Eel River SHaRP Collaborative 2021).

2.2 Distribution

2.2.1 Current

Coho Salmon have a narrower distribution than other salmonids in the Eel River watershed due to their requirement for lower water temperatures. The species is generally confined to cooler, coastal-oriented streams that maintain cool water temperatures throughout the year. Summer distribution is typically limited to locations where maximum weekly average temperature (MWAT) is less than about 17–18 degrees Celsius (°C) (63–64°F) (Welsh et al. 2001, USEPA 2003). However, recent research, however, indicates juvenile Coho Salmon can tolerate higher temperatures, and even exhibit growth, when food resources are abundant (Lusardi et al. 2019).

The current spawning and summer rearing distributions of Coho Salmon are limited primarily to the cooler and more coastal tributaries to the South Fork Eel, Van Duzen, and lower Eel rivers; however small numbers of individuals may be found in Outlook and Tomki creeks and potentially other tributaries to the upper Eel River (Figure D-1). Although spawning and summer rearing are currently concentrated in the colder tributaries, various perennial and intermittent tributaries and mainstem reaches that are too warm or have too little flow to support summer rearing are likely utilized by the species for non-natal rearing during the wet season. The distribution of spawning adults and fry can be strongly influenced by hydrological conditions that occur during the adult migration and spawning periods each year. For example, during winters with sustained flows a greater portion of the population can access smaller streams and headwater reaches compared with dry winters when spawning can be restricted to mainstems and larger tributaries.

Within the South Fork Eel River, the species is widely distributed, but spawning and summer rearing are concentrated in cooler, tributaries draining the western side of the sub-watershed (Guczek et al. 2020, Stillwater Sciences 2022). In the Van Duzen River sub-watershed, Coho Salmon are found primarily in Lawrence Creek, a tributary to Yager Creek (Lam and Power 2016). The species has also been recently documented or listed as occurring in several other tributaries to lower Yager Creek or Van Duzen River, including Cooper Mill, Cummings, Root, and Grizzly creeks (Lam and Power 2016, CDFW 2022).Within lower Eel River below the South Fork confluence, juvenile Coho Salmon have recently been documented in Strongs, Price, Howe, Nanning, Monument, Jordon, Shively, Bear, Chadd, and Bridge creeks (Lam and Power 2016, CDFW/Bios 2022). Juvenile Coho Salmon can also be found in accessible portions of the estuary and its tributaries, including the Salt River and McNulty Slough (Cannata and Hassler 1995, Ross Taylor and Associates 2020).

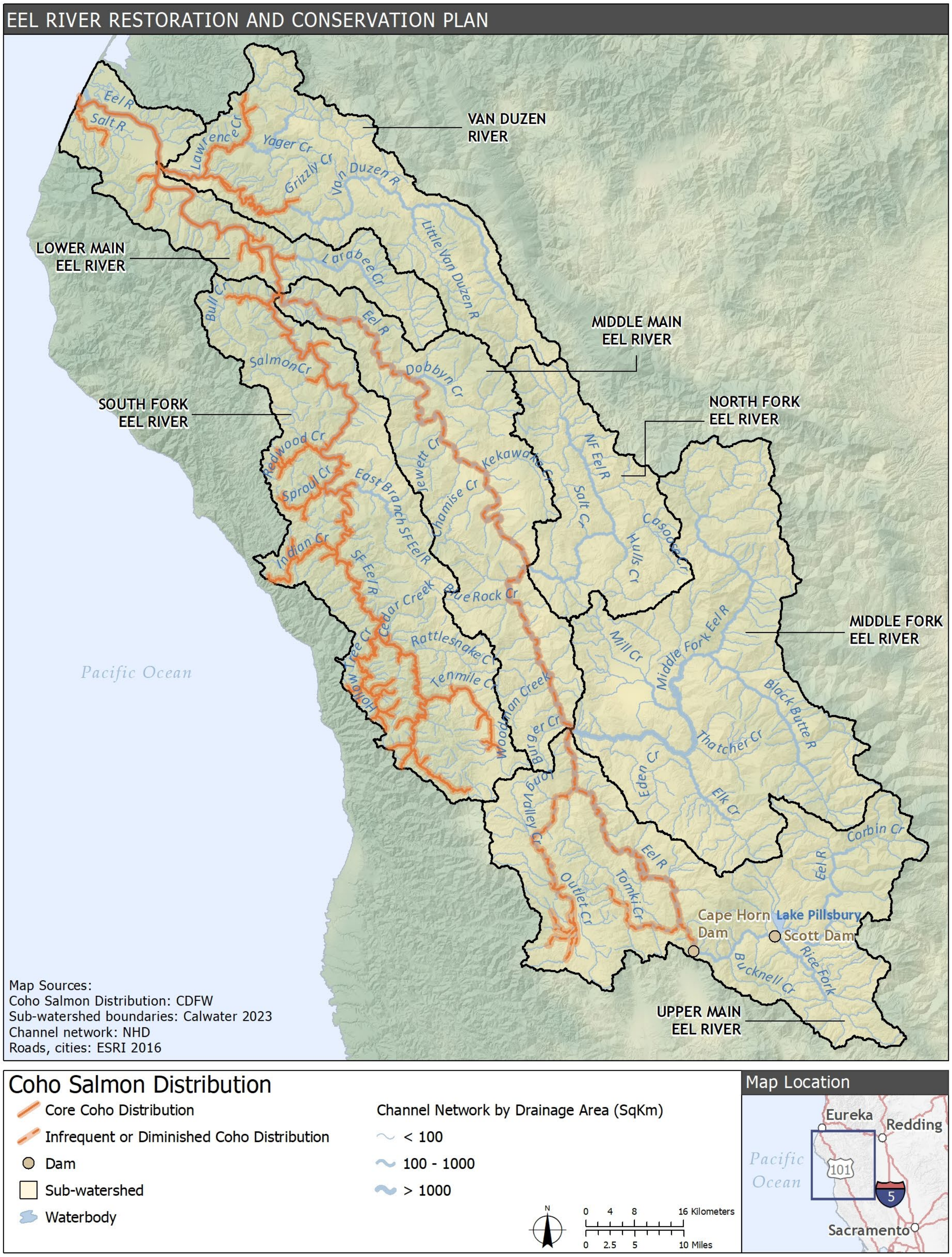

Figure D-1. Approximate current distribution of Coho Salmon in the Eel River watershed. Data source: CDFW Biogeographic Information and Observation System. Does not include various small streams that are likely used seasonally for juvenile rearing. The species is currently rare upstream of the South Fork Eel River.

Small, remnant spawning populations of Coho Salmon may persist in more inland portions of the watershed that maintain cool water temperatures, but inadequate monitoring of many of these streams limit documentation (Brown et al. 1994, Garwood 2012, NMFS 2014). Coho Salmon have been documented in Outlet Creek and several of its tributaries as recently as the early 2000s, but population abundance is thought to be very low and possibly missing two year-classes (Garwood 2012, NMFS 2014).

2.2.2 Historical

Historically, Coho Salmon populations were more widely distributed across the Eel River watershed (Brown et al. 1994). In the upper Eel River, viable populations occurred in both the Outlook Creek and Tomki Creek watersheds (Brown et al. 1994, NMFS 2014). The species has not been documented in Tomki Creek since before 1979, except for one observation in 1996 in its tributary, Cave Creek, and are presumed to be extirpated there (Garwood 2012, NMFS 2014). However, records suggest Coho Salmon used to be abundant in Tomki Creek: during a fish "rescue" in 1949, nearly 17,000 (CDFG 2010). Coho Salmon were also reportedly documented historically in Indian Creek, a mainstem Eel River tributary upstream of Outlet Creek (Brown et al. 1994). Historical presence of the species in the upper Eel River upstream of Scott Dam is unknown (NMFS 2014); but 47 adult Coho Salmon were documented in the mainstem at the Van Arsdale Fisheries Station (VASF) during the 1946–1947 season (Brown et al. 1994). Since then, the species has been rarely observed (in the early 2000s) at VAFS and in small numbers (NMFS 2014). Historical photographs and descriptions of Gravelly Valley—which is blocked by Scott Dam and largely under Lake Pillsbury—show a broad, unconfined valley and complex channel that would have likely provided high-quality juvenile winter rearing habitat for the species (Figure C-1). Coho Salmon are also thought to have been present historically in portions of the Middle Fork Eel River sub-watershed, including Rattlesnake, Mill, Girst, and Rock creeks, but have not been recently documented and are thought to be locally extirpated (Brown and Moyle 1991, Garwood 2012). Prior to widespread habitat degradation and hydrological alteration associated with European settlement and resource extraction, the unconfined, low-gradient channels found in Round Valley (Mill Creek in the Middle Fork Eel River sub-watershed), Gravelly Valley (upper Eel River), and Little Lake Valley (Outlook Creek drainage), likely provided complex and high-quality habitats capable of supporting viable and potentially large populations of the species, while further contributing life-history diversity to overall Eel River Coho Salmon population.

2.3 Ecology, Life-history, and Habitat Needs

2.3.1 Life-history Timing Overview

The generalized life-history timing for Coho Salmon life stages in the Eel River watershed is presented in Table D-1, drawing largely from information in the South Fork Eel River or other northern California populations where more extensive monitoring data are available. Adults typically enter fresh water and migrate upstream to spawning tributaries from November through February (Ricker et al. 2014, Moyle et al. 2017, Guczek et al. 2020). Spawning occurs from November through February, peaking in December and January (Ricker et al. 2014, Guczek et al. 2020). Following deposition in spawning gravels, Coho Salmon eggs incubate for 6–12 weeks before hatching (Murray and McPhail 1988, Moyle et al. 2017) and spend another 4–8 weeks in redd gravels before emerging as fry (Murray and McPhail 1988, Moyle et al. 2017). Following emergence, juvenile Coho Salmon in larger river systems can display a variety of life-history strategies including (1) rearing in natal streams for approximately 1-year before outmigrating to the ocean in the spring; (2) leaving natal streams in the spring soon after emergence and rearing in cool non-natal tributaries or the estuary prior to entering the ocean the following spring or summer; and (3) leaving natal tributaries in the fall or early winter as flows increase and water temperatures decrease and overwintering in suitable low-velocity habitats along in the mainstem corridor, low gradient non-natal tributaries, or in the estuary (Skeesick 1970, Jones et al. 2014, Bennett et al. 2015, Rebenack et al. 2015, Soto et al. 2016). Based on rotary screw trapping data from spawning tributaries in the South Fork Eel River, most individuals emigrate to the ocean as one-year-old smolt between March and July, with peak emigration in April and May (Mendocino Redwood Company 2002, Vaughn 2005, Ricker et al. 2014).

Table D-1. Generalized life-history periodicity of Coho Salmon in the Eel River watershed.

Life stage	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult migration[1,2]												
Spawning[2]												
Incubation[4,5,6,7]												
Juvenile rearing[5,6,8]												
Juvenile movement to non-natal habitats												
Spring fry redistribution[9,10,11]												
Fall juvenile redistribution[9,10,11]												
Smolt outmigration[6,7,8]												

	= Span of activity
	= Peak of activity

[1] CDFG unpubl. Benbow Dam adult count data, 1938–1976
[2] Guczek et al. (2020); CDFW unpubl. data, 2010–2021
[4] Murray and McPhail (1988)
[5] Moyle et al. (2017)
[6] Mendocino Redwood Company (2002)
[7] Vaughn (2005)
[8] CDFG unpubl. Benbow Dam outmigrant trapping data, 1939
[9] Rebenack et al. (2015)
[10] Soto et al. (2016)
[11] Bennett et al. (2015)

2.3.2 Adult Migration

After spending 1 year rearing in fresh water and about 16 months feeding in the ocean, adult Coho Salmon initiate their spawning migration (Sandercock 1991). Early-maturing males known as jacks return to spawn after only 4–6 months in the ocean. Data from historical counts of returning adult salmon conducted at Benbow Dam indicates that jacks typically made up about 23% of the South Fork Eel River Coho Salmon population in most run-years, but ranged from 11% to 55% (CDFG, unpubl. data, 1938–1976).

Adult Coho Salmon in northern California typically enter fresh water and migrate to spawning tributaries from November through February (Ricker et al. 2014, Moyle et al. 2017, Guczek et al. 2020). Historical counts at Benbow Dam on the South Fork Eel River indicate that the first migrating adult Coho Salmon typically arrived in that reach in early to mid-November and the last individuals typically arrived between late January and early February (Stillwater Sciences 2022). In years with limited fall rains, movement of adults into the South Fork Eel River may be delayed until early to mid-December. Historical counts at Benbow Dam indicate the overall median date of adult Coho Salmon arrival at the site was December 14 (CDFG, unpubl. data, 1938–1976, Stillwater Sciences 2022). Apparent adult migration timing based on observations of live adult Coho Salmon from recent spawning surveys conducted in tributaries to the South Fork Eel River is generally consistent with historical counts at Benbow Dam (Guczek et al. 2020).

2.3.3 Spawning and Incubation

Spawning is typically concentrated in the upper mainstem and tributaries of the South Fork Eel River, tributaries to the lower Van Duzen River, and tributaries to the lower Eel River (NMFS 2014, Guczek et al. 2020). Stream flows during the adults migration and spawning periods can strongly influence distribution of spawning and fry, with more spawning in mainstem reaches and larger tributaries expected during dry winters relative to winters, when sustained flows facilitate migration into smaller channels (Lestelle 2007). Coho salmon spawning has been documented in the South Fork Eel River watershed between mid-November and mid-March, but peak spawning typically occurs between early December and mid-February (Guczek et al. 2020; CDFW unpubl. data, 2010–2021). A similar timing is expected for the tributaries to the lower Eel and Van Duzen rivers. Like Chinook salmon, Coho Salmon are semelparous and die after spawning, contributing marine derived nutrients that increase productivity of the stream ecosystem.

Spawning typically occurs loose, silt-free, gravels in pool tailouts, the transitional areas between pools and riffles (Kondolf and Woman 1993, Moyle et al. 2017). Following deposition in redd gravels, Coho Salmon eggs incubate for 6–12 weeks before hatching, with incubation time being inversely related to water temperature (Murray and McPhail 1998, Moyle et al. 2017). After hatching, alevins remain in the redd gravels while undergoing further development and absorption of the yolk sac for another 4–8 weeks before emerging as fry (Murray and McPhail 1988, Moyle et al. 2017). Based on spawning timing, the incubation period, and timing that newly-emerged fry have been captured during outmigrant trapping, developing Coho Salmon eggs or alevins may be present in spawning gravels from approximately November through May (Murray and McPhail 1988, Mendocino Redwood Company 2002, Vaughn 2005).

2.3.4 Juvenile Rearing

In northern California watersheds, Coho Salmon typically rear in fresh water for 1 year prior to emigrating to the ocean in the spring and summer (Rebenack et al. 2015, Moyle et al. 2017), although some individuals may spend 2 years in fresh water (Bell and Duffy 2007, Wright et al. 2012).

Based on length data from outmigrant trapping in South Fork Eel River spawning tributaries (MRC 2002, Vaughn 2005) and nearby watersheds (Maahs 1995, Stillwater Sciences 2023), Coho Salmon fry in the Eel River are expected to begin emerging from redd gravels in late February, with peak emergence from mid-March through mid-May. After emergence, fry seek out low-velocity rearing habitats along the stream margin or in off-channel features. As they grow, juvenile coho, or parr, move to deeper habitats, although they continue to prefer low-velocity habitat throughout the freshwater rearing period (Nickelson et al. 1992). In the summer, Coho Salmon require complex cover and prefer pool habitats (Bisson et al. 1988, Nicholson et al. 1992). Coho Salmon require cool water temperatures and are not typically found in the summer in locations with MWAT >17–18°C (63–64°F) (Welsh et al. 2001, USEPA 2003). However, in locations with abundant food resources, they can tolerate higher temperatures, and even exhibit growth (Lusardi et al. 2019).

During winter, both instream cover and off-channel areas providing slow water are essential for protecting Coho Salmon from displacement by high flows, and for cover from predation (Bustard and Narver 1975, Hartman et al. 1982, Bell 2001). Deep (>1.5 ft), slow (0.5 ft/s) areas within or near cover of roots, large wood, and flooded off-channel habitats, and beaver ponds constitute preferred habitat, especially during freshets (Tschaplinski and Hartman 1983, Swales et al. 1986, Nickelson et al. 1992, McMahon and Hartman 1989, Pollock et al. 2004).

In Northern California, Juvenile Coho Salmon can display a variety of life-history strategies, including: (1) rearing in natal streams for approximately 1 year before outmigrating in the spring as smolt; (2) dispersing from natal streams in the spring as fry and redistributing to thermally suitable non-natal tributaries or the estuary, where they rear prior to entering the ocean the following spring or summer; and (3) leaving natal tributaries in the fall or early winter with increasing stream flows and decreasing water temperatures and overwintering in low-velocity habitats along in the mainstem corridor, low-gradient non-natal tributaries, or the estuary (Jones et al. 2014, Rebenack et al. 2015, Soto et al. 2016). In northern Washington streams with minimal estuarine habitat, Juvenile Coho Salmon have also been documented entering the marine environment in their first fall or winter (age-0) and returning as adults approximately 2 years later (Bennett et al. 2015).

As discussed above, some individuals can also spend 2 years in fresh water, likely rearing in some combination of natal and non-natal habitats during that time (Bell and Duffy 2007, Wright et al. 2012). The extent to which these life-history strategies are expressed in the Eel River watershed and how their prevalence varies amongst spawning tributaries is uncertain due to limited juvenile monitoring, particularly outside of spring and summer. Their historical incidence is also largely unknown, but life histories at are currently rare were presumably more common under more pristine conditions. Section 1.4.1 provides additional description of these life-history strategies, including describing variations within each strategy, their expected distributions within the Eel River, factors that influence their relative prevalence, and restoration considerations for each.

2.3.5 Smolt Outmigration

Outmigrant trapping conducted in the spring and early summer in various South Fork Eel River tributaries and nearby watersheds indicates that most Coho Salmon smolt outmigrate from natal streams from early March through late May, but small numbers have been documented moving at late as mid-June in some streams (Puckett 1976, Maahs 1995, PCFFA 1988, MRC 2002, Vaughn 2005). A single year of juvenile outmigrant trapping at Benbow Dam in 1939 suggests that outmigration of juvenile Coho Salmon in the mainstem South Fork Eel River likely occurs soon after outmigration from tributaries: peak capture at Benbow occurred in early to mid-May, with over 75% of annual captures by mid-May (CDFG unpubl. Benbow Dam outmigrant trapping data, 1939 as cited in Stillwater Sciences 2022). Juvenile Coho Salmon were first captured on April 3 and last captured on July 27, but very few individuals were caught after late June (Stillwater Sciences 2022).

After leaving the South Fork Eel and Van Duzen Rivers, smolting Coho Salmon utilize the lower Eel River and estuary as transitional habitat between fresh and salt water (Puckett 1977, Cannata and Hassler 1995, Ross Taylor and Associates 2020). Puckett (1977) captured age-1 juvenile Coho Salmon in the Eel River estuary from spring through summer, with most individuals captured in April, May, and June. The typical duration of time spent in the estuary before entering the ocean is unknown, but presence of individuals considerable distances up the McNulty Slough and Salt River drainages suggests that at least some juveniles rear in these areas prior to entering the ocean. Puckett (1977) also captured a single juvenile Coho Salmon in late October and Cannata and Hassler (1995) captured several individuals in December and February. More recently, small numbers of juvenile Coho Salmon have been captured in the Salt River from November through May, indicating that some component of the population likely leaves natal tributaries for the estuary prior to spring (when outmigrant trapping efforts were typically initiated).

2.3.6 Ocean Residence

After entering the ocean in the spring or summer, Coho Salmon typically spend about 16 months feeding in the ocean before initiating their spawning migration (Sandercock 1991). Early-maturing males known as jacks return to spawn after only 4–6 months in the ocean. Movement patterns and distribution of Coho Salmon in the ocean are not well described, but individuals from northern California rivers are generally thought to range along the northern California and southern Oregon coasts south of Cape Blanco (Weitkamp and Neely 2002). Ocean conditions, especially during the first few months of ocean residency, have a large influence on smolt-to-adult survival (Bradford 1995, Quinn 2005). Strength and timing of ocean upwelling from the California Current and its influence on marine productivity are key factors affecting marine survival of juvenile salmon (Nickelson 1986, Ruzicka et al. 2011). Interannual differences in ocean conditions and upwelling are driven in part by the Pacific Decadal Oscillation, which can influence the food chain and quantity and quality of food for young salmon (Ruzicka et al. 2011, Peterson et al. 2012). An in-depth review of the influences of interannual variability and changes in ocean conditions in Coho Salmon marine survival can be found in NMFS (2014).

2.4 Life-history Diversity Conceptual Model

This section synthesizes information from the Eel River and elsewhere within the range of Coho Salmon to identify and characterize juvenile and adult life-history strategies with potential to occur in the watershed. Additional, likely rare or extirpated, strategies with potential to contributed to population abundance are resilience in the Eel River are also briefly described. The overall approach, rationale, and uses of these life-history conceptual models in the context of the Restoration Plan are described in Section 3 of the Plan.

2.4.1 Juvenile Life-history Strategies

Juvenile Coho Salmon in the Eel River have potential to display a wide range of life-history pathways, utilizing various habitats across the watershed from the time of emergence from redd gravels until they enter the ocean (Figure D-2). While the total number of possible pathways that could occur is too many to describe individually, they can be grouped into the following three primary strategies, ordered by decreasing time spent in natal streams (Figure D-3):

1. **Natal stream rearing**: rear in natal streams for approximately 1 year before outmigrating in the spring as smolt;
2. **Fall parr emigrant**: rear in natal streams from emergence until fall or early winter before overwintering in the mainstem corridor, non-natal streams, or the estuary prior to entering the ocean in the spring or summer;
3. **Spring fry emigrant**: dispersing from natal streams in the spring as fry and redistributing to thermally suitable non-natal tributaries or the estuary, where they rear prior to entering the ocean the following spring or summer

The extent to which these life-history strategies are expressed in the South Fork Eel River watershed and how their prevalence varies amongst spawning tributaries is uncertain due to limited juvenile monitoring outside of spring and summer.

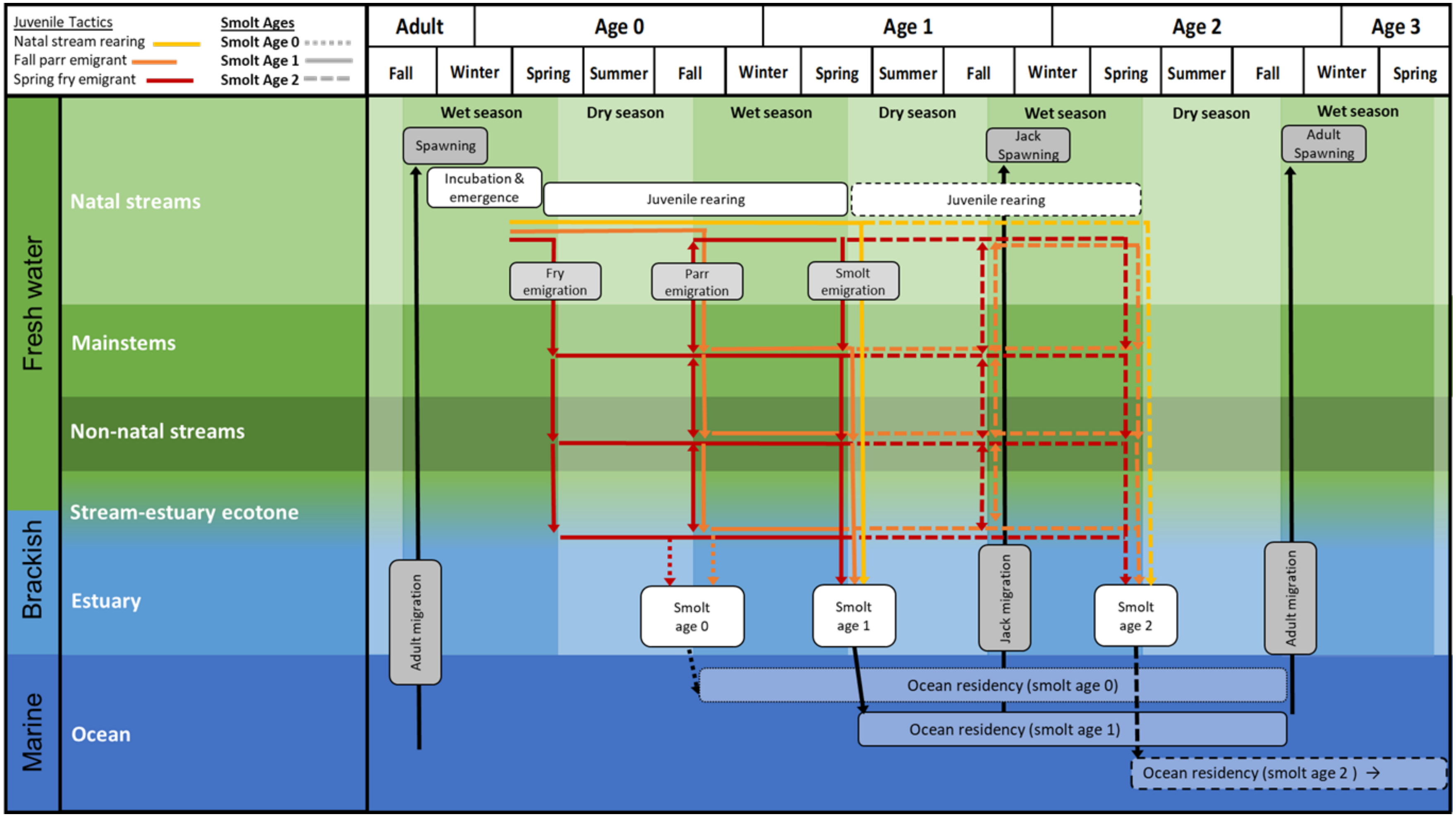

Figure D-2. Life-history conceptual diagram for Coho Salmon in the Eel River, showing potential pathways across time and space for primary juvenile life-history strategies, which are represented by yellow, orange, and red. Each line represents a potential pathway within a strategy. Arrows direction represents movement direction of movement between primary portions of the watershed.

2.4.1.1 Natal Stream Rearing Strategy

The natal stream rearing strategy, which spends the majority of its approximately 1-year freshwater residency in the stream where it hatched before emigrating to the ocean in the spring, is the most recognized and intensively monitored Coho Salmon juvenile life-history in Northern California. Because this strategy must persist through variable environmental conditions across all four seasons before emigrating to the ocean, it is expected to be more prevalent in streams with high-quality habitat conditions in both the dry and wet seasons. In the dry season, these habitat conditions include perennial flows, cool water temperatures, and complex pool habitats that provide escape cover (Bisson et al. 1988, Nicholson et al. 1992). In the wet season, these conditions include low-velocity winter rearing and high-flow refuge habitats provided by large wood and connected off-channel features, which are more prevalent in low-gradient, unconfined channels (Bustard and Narver 1975, Hartman et al. 1982, Nickelson et al. 1992).

Conditions that support the natal stream rearing strategy are primarily found in the low-gradient cold and cool tributary channel archetypes (Plan Section 2.2 and Appendix C). Within the Coho Salmon distribution in the Eel River, cool streams with persistent summer flows are generally associated with watersheds that have a relatively low fraction of Central Belt mélange geology and a high fraction of Coastal Belt geology, which acts to slow and retain winter run-off and slowly drain groundwater during the summer (Dralle et al. 2023). Conditions that support natal rearing currently occur primarily in the more coastal-oriented spawning tributaries, such as Indian Creek in the South Fork Eel sub-watershed and Lawrence Creek in the Van Duzen sub-watershed. However, natal rearing is expected to have been more prevalent in other parts of the watershed historically, before widespread alteration of channel, riparian, and hydrological conditions.

Within their natal streams, the prevalence of the natal rearing strategy relative to early emigrant strategies is expected to vary between years with different hydrological conditions. For example, in dry water years, both the thermal suitability and physical capacity of summer rearing habitat in these streams may be reduced, resulting in a greater fraction of spring fry emigrants. In wetter years with significant high flow events, the winter rearing habitat capacity of some natal streams may be reduced, resulting in a great fraction of individuals that either volitionally emigrate or are entrained downstream in the fall or winter prior to smolting (fall parr emigrants). As described below, habitat and ecological conditions in non-natal rearing habitats and during movements to reach them are expected to determine the extent to which these early emigrant strategies survive and contribute to adult returns.

Individuals within the natal stream rearing strategy there are expected to display a range of behaviors that contribute additional life-history diversity to the population. For example, some individuals may spend much of their freshwater residency in the same general location, while some individuals are expected to move downstream or upstream within natal streams in response to changing flows, availability of food, and other seasonal ecological changes. Additionally, in a typical year, timing of smolt emigration from natal streams ranges from early March until at least mid-June (Puckett 1976, Maahs 1995, PCFFA 1988, MRC 2002, Vaughn 2005), with early emigrants often encountering vastly different environmental and ecological conditions than late emigrants. Likewise, the amount of time natal stream rearing smolts spend in lower mainstem the estuary before entering the ocean is expected to vary. Because this diversity provides additional population resilience it is important to consider ways to protect and enhance it when developing restoration strategies.

2.4.1.2 Fall Parr Emigrant Strategy

The fall parr emigrant strategy spends its first spring and summer rearing in natal streams before emigrating to low-velocity, non-natal winter rearing habitats as temperatures drop and flows rise in the fall. Various studies have shown a large initial pulse of juvenile Coho Salmon movement in response to the first substantial increases in stream flow in the fall (i.e., freshets), and continued pre-smolt movements throughout the fall in winter, typically in response to additional flow increases (Petersen 1982, Scarlett and Cederholm 1984, Miller and Sadro 2003, Stillwater Sciences 2023). Though the fall parr emigrant strategies has not been directly documented in the Eel River through outmigrant trapping or tagging studies, presence of juveniles in the estuary and its tributaries in the fall and winter (Cannata and Hassler 1995, Ross Taylor and Associates 2020) indicate the strategy is still present and likely an important contributor to the overall Eel River Coho Salmon population.

Fall-to-winter redistribution by juvenile Coho Salmon has been documented in numerous other river systems, including migrations into small, intermittent tributaries (Ebersole et al. 2006, Wigington et al. 2006), perennial tributaries (Skeesick 1970, Soto et al. 2016, Stillwater Sciences 2023); off-channel ponds, beaver ponds, and wetlands along the mainstem river corridor (Petersen 1982, Miller and Sadro 2003, Soto et al. 2016); and estuarine habitats such as tidal wetlands and sloughs (Miller and Sadro 2003, Koski 2009, Jones et al. 2014, Rebenack et al. 2015, Wallace et al. 2015). Some of these fall movements occur over relatively short distances, while others can involve long distance emigration to overwintering habitats (Petersen 1982, Ebersole et al. 2006, Soto et al. 2016, Stillwater Sciences 2023). For example, studies in the Klamath River have documented fish tagged in the summer in inland spawning tributaries moving over 100 miles downstream to rear in the lower reaches of non-natal tributaries (Adams 2013, Soto et al. 2016). Different individuals tagged leaving the same spawning stream have been documented using non-natal habitats distributed across large distances along the mainstem corridor (Soto et al. 2016).

Many of these non-natal winter rearing habitats are expected to provide high-quality food resources and offer winter growth and survival advantages relative to natal streams. Estuarine habitats in particular can provide abundant food resources and promote high juvenile salmon growth rates (Miller and Sadro 2003, Koski 2009, Wallace et al. 2015). Because of enhanced growth and survival, fall emigrants that rear in the estuary can contribute disproportionately to adult returns (Bennett et al. 2014, Jones et al. 2014).

Small streams, even those that become intermittent in the summer, can also provide high-quality rearing and winter refuge habitat for fall parr emigrants during the wet season (Skeesick 1970, Ebersole et al. 2006, Wigington et al. 2006). Ebersole et al. (2006) found high overwinter survival and growth rates in a small tributary relative to adjacent mainstem reaches. This study also showed that some individuals may enter and leave multiple tributaries and use a wide array of habitats during the winter. These findings highlight the importance of small streams to Coho Salmon populations (and especially early emigrant strategies) and the importance of maintaining and restoring access to these habitats. Low-gradient tributaries that are downstream of a large portion of Coho Salmon spawning locations, such as tributaries entering the lower Eel River are expected to have particularly high potential to provide valuable non-natal rearing habitat for fall parr emigrants, since much of emigrant population has an opportunity to enter them. For this reason, assessing and restoring habitat in and connectivity to these streams is an important strategy for increasing the prevalence of the fall parr emigrant strategy.

In addition to the downstream movements described above, fall parr emigrants can also undertake considerable upstream movements from the lower reaches of larger streams into upper reaches or smaller upstream tributaries. This behavior, often associated with the first freshets of fall, has been described by various studies (Miller and Sadro 2003, Koski 2009, Nordholm 2014, Stillwater Sciences 2023). While some of these fish documented moving upstream in the fall were likely offspring of fish that spawned in lower mainstem reaches, in many cases these fish initially entered the stream-estuary ecotone as fry in the spring or summer before moving back upstream in the fall. The latter life-history pathway has been referred to as "fry-nomad migrants" (Miller and Sadro 2003, Koski 2009) and is described in more detail in the Section 2.4.1.3 (s*pring fry emigrant*) below.

The prevalence of the fall parr emigrant in the Eel River watershed is expected to vary by both annual differences in hydrological conditions and spawning location. Timing and magnitude of stream flows are expected to influence the fraction of the population in a stream that emigrates in the fall versus in the spring as smolts. In general, high flows that result from wet falls and winters are expected result in more early emigration relative to drought winters, when in-channel water velocities remain lower and fewer fish are entrained downstream.

The fall parr emigrant strategy is expected to be a component of the juvenile population in most, if not all, streams where Coho Salmon spawn, but is hypothesized to be more prevalent in locations that have high-quality summer rearing habitat but lack winter high flow refuge habitat. For example, much of mainstem Hollow Tree Creek—which has high-quality spawning and cool summer rearing habitat but generally lacks high-flow refuge habitat due to its large size and confined channel—is a natal stream that likely promotes a high degree of juvenile emigration in the fall. As flows rise, many individuals that reared in the mainstem of Hollow Tree Creek in the summer are likely forced to enter low-gradient tributaries or leave the watershed and seek overwintering habitats downstream. This fall redistribution could include entering off-channel features along the corridors of the South Fork or mainstem Eel Rivers Eel River, low-gradient tributaries, or estuarine habitats. Importantly, various small tributaries that do not support Coho Salmon spawning or are too hot or dry to support summer rearing have high potential to provide high-quality overwintering habitats. The extent of winter use of such streams by Coho Salmon is largely unknown in the Eel River due to the focus of existing monitoring on cold, perennial streams in the summer.

The fall parr emigrant strategy was likely much more prevalent in the Eel River historically, before the extensive degradation the estuary; large, unconfined valleys that provided extensive winter rearing habitat such as Little Lake Valley (Outlook Creek) and Laytonville Valley (Ten Mile Creek); and other non-natal winter rearing habitats. Nevertheless, the strategy is likely still an important component of the Eel River Coho Salmon population, and one that has great potential to be restored. The various studies described above highlight the importance of connectivity between mainstems and adjacent low-velocity winter rearing habitats such as low-gradient tributaries and off-channel features along mainstem corridors and the estuary. Impassible road culverts and tide gates block juvenile fish access to many of these habitats. Likewise, levees and rip-rapped roads along portions of the South Fork, Van Duzen, and Eel rivers have disconnected many floodplain habitats that likely provided extensive winter rearing habitat historically.

Despite their potential to provide high-quality winter habitat, warmer, drier streams have largely been overlooked in efforts to restore Coho Salmon populations in the Eel River. Along mainstem river corridors, low-velocity winter rearing habitats may occur in floodplain channels with ponded features or off-channel ponds connected to the mainstem by small channels (Soto et al.

2016). Such features are often associated with small tributaries, which can (1) help maintain connectivity with the mainstem; (2) improve water quality in off-channel habitats during drier winter periods; and (3) provide clearwater feeding habitats during high flows when high turbidity levels in adjacent mainstems can cause negative physiological effects, impair feeding, and prompt juvenile salmon to seek refuge habitats (Bisson and Bilby 1982, Sigler et al. 1984, Sedell et al. 1990, Soto et al. 2016).

Alteration of much of the lower mainstems of the South Fork, Van Duzen, and Eel rivers and the lower reaches of their tributaries due to highway and levee construction, as well as sediment deposition from logging and large floods, has likely degraded or disconnected many of the off-channel features that existed historically. Such changes are expected to have lowered the survival and prevalence of the fall par emigrant strategy. Likewise, widespread degradation and disconnection of estuarine winter habitats due to diking, tide gates, and agricultural conversion is expected to have has diminished this important component of juvenile Coho Salmon life-history diversity in the Eel River. Loss of mainstem habitat complexity and the introduction of non-native Sacramento Pikeminnow has also likely resulted in decreased survival off fall emigrants during movements from natal to non-natal habitats, further diminishing the prevalence of this strategy.

2.4.1.3 Spring Fry Emigrant

The spring fry emigrant strategy of juvenile Coho Salmon leaves natal streams in the spring or summer as flows recede and water temperatures warm. Some newly emerged fry may be entrained downstream by higher spring flows (Tschaplinski 1987), while others likely move in response to warming temperatures or shrinking habitat as flows drop in natal streams (Koski 2009). The extent to which fry emigrants are entrained by stream flows, are "surplus" fry that exceed the carrying capacity by summer rearing habitat or are displaying an ingrained life-history strategy that occurs regardless of density-depending mechanisms is unknown. It is likely that each of these factors interact to contribute to fry emigration from a natal stream, and the number of individuals moving on account of each factor varies annually depending on spawning density and hydrological conditions that influence spawning (and emergence) locations, fry entrainment, and summer carrying capacity. Regardless of the reason, evidence from various watersheds indicates that enough early fry emigrants can survive to contribute substantively to the returning adult population (Koski 2009, Jones et al. 2021).

After leaving natal streams, spring fry emigrants can move through and rear in a variety of habitats across time and space before entering the ocean the following spring (Figure D-2). After moving, some individuals remain in a single location through the summer and winter until smolting. Others may display more of a nomadic life-history pathway, where they move between multiple habitats in response to changing environmental conditions and food resources (Lestelle 2007, Koski 2009, Soto et al. 2016, Jones et al. 2021). While some fry emigrants initially enter non-natal tributaries, many are expected to enter mainstem habitats soon after emergence from natal streams in the spring. Spring movement of Coho Salmon fry from natal streams into the mainstem South Fork Eel River has been documented by outmigrant trapping in various tributaries (Puckett 1976, PCFFA 1988, Maahs 1995, Vaughn 2007). Some of these fry likely continue moving downstream to the stream-estuary ecotone, but, at least historically, others may have reared in productive habitats in and adjacent to the mainstem through the spring and early summer. Based on research in other large river systems, these fry seek out low-velocity habitats, such as backwaters, edge habitats along mainstem floodplain channels including ponds (particularly those fed by small tributaries), and small low-gradient tributaries (Peterson 1982, Beechie et al. 2005, Soto et al. 2016). During the spring and early summer, water temperatures in mainstem reaches of the South Fork Eel, Van Duzen, and lower Eel rivers typically remain suitable for juvenile Coho Salmon (Asarian et al. 2016, Stillwater Sciences and Wiyot Tribe Natural Resources Department 2020). Because these mainstem reaches (and some non-natal tributaries) are warmer and receive more solar exposure, they are expected to be more productive and provide growth advantages for fry in the spring relative to colder natal streams.

Since many mainstem reaches become thermally unsuitable for Coho in the summer Asarian et al 2016), remaining fry must either seek out thermal refugia within mainstem reaches or redistribute to cooler habitats in tributaries, the stream-estuary ecotone, or upstream reaches. Such an early summer redistribution has been described in the nearby Klamath River watershed (Adams 2013, Soto et al. 2016). In addition to downstream movements or entering tributaries, upstream movements within mainstem reaches can occur in the summer. For example, in the Shasta River, Adams (2013) documented extensive upstream movements of age-0 Coho Salmon tagged in the late-spring from mainstem locations to cooler reaches in the upper mainstem and adjacent tributaries. Observations by Georgakakos (2020) suggest similar movements may occur into the upper reaches of the South Fork Eel River, where water temperatures can remain suitable throughout the summer rearing period.

The historical and current prevalence of Coho Salmon summer rearing in larger mainstem reaches is unknown but would require thermal refugia provided by coldwater plumes at from tributaries, springs or groundwater seeps, or thermally stratified pools. Limited monitoring has been conducted to document the distribution and temperature patterns of thermal refugia within the range of Coho Salmon in the Eel River watershed, but such feature do occur (e.g., Kubicek 1977, Nielson et al. 1994, Wang et al. 2020) and have potential to support the spring fry emigrant strategy. In the mainstem Klamath River, Deas and Tanaka (2006) documented age-0 Coho Salmon rearing in several thermal refuge sites associated with tributary confluences. Similar refuges are expected to exist at confluences of various cold tributaries to the South Fork Eel, lower Eel, and lower Van Duzen rivers. However, the presence of large numbers of introduced Sacramento Pikeminnow is hypothesized to have greatly limited the ability of juvenile Coho and other salmonids to utilize these and other productive mainstem habitats, both in the spring and summer.

Spring fry migrants that move quickly through mainstem reaches may rear in habitats within the stream-estuary ecotone. One life-history pathway that appears to be common in various river systems is downstream movement into the stream-estuary ecotone in the spring, followed by upstream movement into tributaries or adjacent off-channel habitats as mainstem flows and water velocities increase in the fall (Skeesick 1970, Koski 2009, Miller and Sadro 2003, Stillwater Sciences 2023). In this pathway, individuals feed and grow in productive lower river and brackish estuarine habitats before seeking low-velocity habitats for winter rearing. The current prevalence of this life-history pathway in the Eel River is unknown, but is presumed to be rare relative to historical conditions because of the extensive modification of the lower mainstem corridor and estuary, including rail road, road, and levee construction; reduced supply of large wood; channel aggradation that resulted in filling of deep pools and a reduced tidal prism; and the introduction of predatory Sacramento Pikeminnow, which occur in high densities in lower mainstem habitats that could otherwise support large numbers of salmonids (CDFG 2010).

After summer, depending on the conditions within their summer rearing location, some spring fry emigrants may redistribute again to one of the suitable low-velocity winter habitats described above for the fall parr emigrant strategy (e.g., estuary, small, low-gradient tributaries etc..).

The spring fry emigrant strategy is expected to be a component of the juvenile population in all streams where Coho Salmon spawn, but is hypothesized to be more prevalent in natal streams with poor fry habitat (lack of low velocity edgewater habitat) or with summer water temperatures that approach or exceed levels suitable juvenile rearing, such as many of the streams draining the eastern side of the South Fork Eel River watershed (e.g., Dean Creek, East Branch South Fork Eel River, and Ten Mile Creek). As discussed above the annual differences in hydrological conditions is also expected to pay a role in prevalence of fry emigrants. Distribution of spawning and emergent fry can be strongly influenced by stream flows during the adult migration and spawning periods. For example, during winters with sustained flows a greater portion of the spawning population can access smaller streams and headwater reaches that stay cool through the summer. In contrast, during dry winters spawning and fry emergence can be restricted to mainstems and larger tributaries. Following dry winters, a greater fraction of the population is hypothesized to emigrate as fry since (1) larger channels may become thermally unsuitable during the summer and (2) lower summer base flows may constrict summer habitat carrying capacity force more individuals to seek downstream habitats.

2.4.1.4 Other juvenile life-history strategies

Various other less common juvenile Coho Salmon life-history strategies may occur or may have occurred to a greater degree prior to extensive degradation of certain habitats that supported unique life-history strategies. For example, populations that occurred in large, more inland valleys such as Little Lake Valley and Round Valley have been severely reduced or extirpated, but likely used to support juveniles with unique life-history strategies. Some strategies with potential to occur in the Eel River watershed and contribute to the population resilience are briefly described below.

Age-2 smolt

Each of the primary strategies described above typically spends about 1 year in fresh or brackish water before entering the ocean. However, some juvenile Coho Salmon may spend 2 years in fresh water (Holtby 1990, Bell and Duffy 2007, Wright et al. 2012), displaying one or more of the primary strategies during this time. In general, the proportion of 2-year-old smolts in a population increases with increasing latitude, which is thought to be due to slower growth with colder water temperatures (Holtby 1990, Sandercock 1991). However, 2-year freshwater residency has documented to varying degrees in Northern California Coho Salmon populations (Bell and Duffy 2007, Wright et al. 2012, Stillwater Sciences 2023). For example, in Prairie Creek, Bell and Duffy (2007) found that 28% of outmigrants spent 2 years in fresh water and attributed the high prevalence of age-2 smolt to low winter growth rates. In Pudding Creek, Wright et al. (2012) found that, over a 5-year study, 13% of Coho smolt were age-2 smolt, though incidence varied by year. Further, they found that, when initially tagged after about 1 year in fresh water, individuals that went on to smolt at age-2 were smaller (median fork length 76 mm) than those that smolted at age-1 (92 mm). However, measured just entering the ocean, the median length of age-2 smolt was greater (129 mm) than age-1 smolt (104 mm). While this age-2 smolt life-history has not been well described in the Eel River, length data from outmigration trapping in South Fork Eel River tributaries indicates it occurs to some degree (Pucket 1976, MRC 2002).

The age-2 smolt life-history likely influences population dynamics and contributes to resilience of Coho Salmon populations in several important ways. First, a second year of growth allows smaller individuals to emigrate at a larger size, increasing the likelihood of marine survival. Second, since many age-2 smolt are expected to return to spawn at age-4, a year later than age-1 smolt in their cohort, they promote genetic mixing between spawning cohorts. Finally, if spawning recruitment and juvenile survival are poor for a given cohort, age-2 smolt from the previous cohort can contribute to the returning adult population of that cohort.

Age-0 smolt

Coho salmon that smolt and enter the ocean at age-0 appear to be rare but have been documented in several instances across the range of the species (Koski 2009, Adams 2013, Shaul et al. 2013, Bennett et al. 2014). In the Klamath basin, considerable numbers of age-0 smolt have been documented leaving the Shasta River, where extremely high spring growth rates can occur in spring and summer (Adams 2013, Lusardi et al. 2019). Coho Salmon have also been observed leaving small Olympic Peninsula streams in Washington and entering the ocean at age-0, primarily during the fall (Roni et al. 2012, Benett et al. 2014). These streams have limited estuaries and discharge directly into the Strait of Juan de Fuca, suggesting that these age-0 fish may have been entrained into the ocean as flows increased in the fall. However, PIT tag data indicated that this fall smolt life-history contributed 37% of the returning adults over an 8-year period, and that half of the individuals spent about 1 year at sea and half spent 2 years at sea (Bennett et al. 2014). Some of individuals moved through the marine environment to overwinter in nearby watersheds or reentered their natal watershed (Roni et al. 2012). This phenomenon—which has been termed "habitat shifting through the marine environment" (Lambet and Chamberlin 2023)—has also been documented between tributaries in Southeast Alaska (Shaul et al. 2013), between the Klamath River and Prairie Creek (Faukner et al. 2017), and between Humboldt Bay tributaries (Wallace et al. 2015).

Smoltification and ocean entry at age-0 is expected to be rare under current conditions in the Eel River, but insufficient monitoring has been conducted to understand its true prevalence. It is possible that, when pristine, certain habitats in the Eel River watershed (e.g., the large, connected wetland habitats that used to exist in Little Lake Valley in the Outlet Creek watershed) promoted rapid fry growth and smoltification at age-0. This life-history strategy could influence population dynamics and resiliency since it would allow for genetic mixing between spawning cohorts. Due to rapid growth and the short amount of time spent in fresh water, fry to smolt survival be higher and generation time would be faster.

Relict Inland Populations

TO EXPAND / REFINE FOR FINAL

Although currently absent or rare, there is some evidence that viable populations of Coho Salmon have historically reared in more inland locations such as Mill Creek in Round Valley, Outlet Creek, and Tomki Creek (Section 2.2.2). Due to the likely higher summer water temperatures, it is possible that fry migrants were prevalent in these populations. Although, under historical conditions with intact hydrology and riparian, oversummering may been more prevalent. Because of their high intrinsic potential to support Coho Salmon and promote further life-history diversity in the Eel River, large valleys such as Little Lake Valley near Willits (Outlet Creek drainage) and Round Valley warrant additional attention.

2.4.2 Adult Life-history Strategies

TO COMPLETE FOR FINAL

The primary life-history variation in adult Coho Salmon is related to (1) age at return to fresh water and (2) variability in run and spawning timing.

Age at Spawning

Adult Coho Salmon typically return as either 3-year-old adults or 2-year-old jacks.

Data from historical counts of returning adult salmon conducted at Benbow Dam indicates that in typical run-years jacks made up about 25% of the South Fork Eel River Chinook salmon population, but ranged from 9% to 75% (CDFG, unpubl. data, 1938–1976 as cited in Stillwater Sciences 2022). These values are similar to jack percentages documented in southern Oregon coastal streams (Young 2011). Young (2011) suggested that jacks could be critically important in maintaining genetic structure of coho populations because they provide the only gene flow between otherwise isolated brood years for the species.

Run Timing Variability

2.5 Conceptual Model Outcomes

The information compiled and understanding gained from this species descriptions and life-history conceptual model was used to:

- Identify a draft list of likely stressors;
- Identify and describe key themes and strategies for restoration and conservation; and
- Catalog important data gaps to help identify research and monitoring activities needed to address them.

2.5.1 Stressors

For final: to complete and add working table of key stressors for Coho Salmon and add a narrative discussing likely population bottlenecks.

2.5.2 Restoration Take-home Points

To be completed for Final. Plan Section 3.2.4.2 summarizes most of the key points related to Coho Salmon.

2.5.3 Data Gaps and Research Needs

Section to be completed/expanded for Final Plan

During this review, several gaps in understanding of distribution, life-history, and abundance of Coho Salmon that limit effective management and restoration of the species in the Eel River watershed were identified. Key data gaps include:

- Juvenile survival and variability across watershed.
- Current prevalence and distribution of early emigrant life-history strategies in non-natal rearing habitats within and between years with variable environmental conditions—including in mainstems, adjacent off-channel habitats, warm and cool non-natal tributaries, and the estuary.
- Historical prevalence and distribution of juvenile life-history strategies.
- Habitat use and distribution during the fall, winter, and spring.
- Timing of movements between natal streams and non-natal rearing habitats and survival during these movements.
- Estuarine movements, habitat use, and prevalence of stranding.
- Use of thermal refugia in mainstems.

- Seasonal movements within natal streams.
- Presence day occurrence and abundance in inland watersheds with high intrinsic potential and cool water, where the species may have been historically present or abundant, but where monitoring is insufficient to document. Specifically, Outlook Creek, Tomki Creek watersheds, and the Mill Creek drainage in the Middle Fork sub-watershed.
- Smolt production from important spawning streams.
- Survival of emigrating smolt or juveniles between natal streams and the ocean across time and space. Where are the mortality hotspots and why?
- Impacts of pikeminnow predation and presence and how these impacts vary spatially and temporally.
- Ocean survival and influences of ocean conditions, prey composition and abundance, harvest management practices, and bycatch from other fisheries.

2.6 References (Coho Salmon)

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3 STEELHEAD

3.1 Population Structure and Status

(*Oncorhynchus mykiss* [*O. mykiss*]) are considered the most flexible salmonid species—both behaviorally and physiologically—in the Eel River watershed, exhibiting a diverse array of juvenile rearing and adult maturation/migration strategies (Shapovalov and Taft 1954, Kendall et al 2015). There are three primary *O. mykiss* maturation strategies in the Eel River: resident Rainbow Trout, winter-run steelhead, and summer-run steelhead. Resident Rainbow Trout complete their lifecycle in freshwater, often in their natal stream. Winter-run steelhead migrate to the ocean as juveniles, spend one or more years at sea, and then return to freshwater in the winter as reproductively mature adults to spawn. Summer-run steelhead also migrate to the ocean as juveniles but return to freshwater earlier in the year—typically between late spring and summer—as reproductively immature adults (a strategy called "premature migration"). Summer-run adults remain in freshwater while maturing and then spawn in the winter. In addition to these three primary ecotypes, the adult steelhead population includes a potentially distinct "fall-run" component (akin to that described in the Klamath River) (Roelofs 1983). Fall-run adults are thought to enter freshwater in late summer or early fall and then hold in the lower mainstem Eel River until rainstorms facilitate upstream movement into spawning reaches in late fall and winter. Unlike salmon, steelhead are iteroparous; some individuals return to the ocean after spawning as "kelts," and may return to freshwater the following winter to breed again.

Steelhead in the Eel River watershed are part of the Northern California Distinct Population Segment (DPS), which is listed as threatened under the federal Endangered Species Act (ESA) (NMFS 2006). The Northern California DPS includes all naturally spawned steelhead originating from Redwood Creek in Humboldt County southward to—but not including—the Russian River (NMFS 2006). Steelhead populations in the lower mainstem Eel River and South Fork Eel River sub-watersheds are included in the North Coastal Diversity Stratum, populations in the middle mainstem Eel River sub-watershed are included in the Lower Interior Diversity Stratum, and populations in the Van Duzen, North Fork Eel, and Middle Fork Eel river sub-watersheds (and accessible portions of the upper mainstem Eel River sub-watershed) are included in the North Mountain Interior Diversity Stratum. Winter-run and summer-run steelhead are not considered separate listing entities under the federal ESA (NMFS 2020), though the Eel River is one of the southernmost watersheds with an extant summer-run sub-population (Jones 1992). In contrast, summer-run steelhead in the Northern California DPS are listed as endangered under the California ESA (CESA), while winter-run steelhead are not considered warranted for listing (CFGC 2022). Fall-run steelhead are not provided separate protection. Non-anadromous Rainbow Trout are not currently considered a separate listing entity, despite freely interbreeding with steelhead in streams where they co-occur (Harvey et al. 2021). However, any *O. mykiss* occurring downstream of impassable barriers in the Eel River have the potential to be anadromous and thus are afforded the associated statutory protections.

3.2 Distribution

The distribution of winter-run steelhead, summer-run steelhead, and resident Rainbow Trout within the Eel River watershed are discussed in detail below.

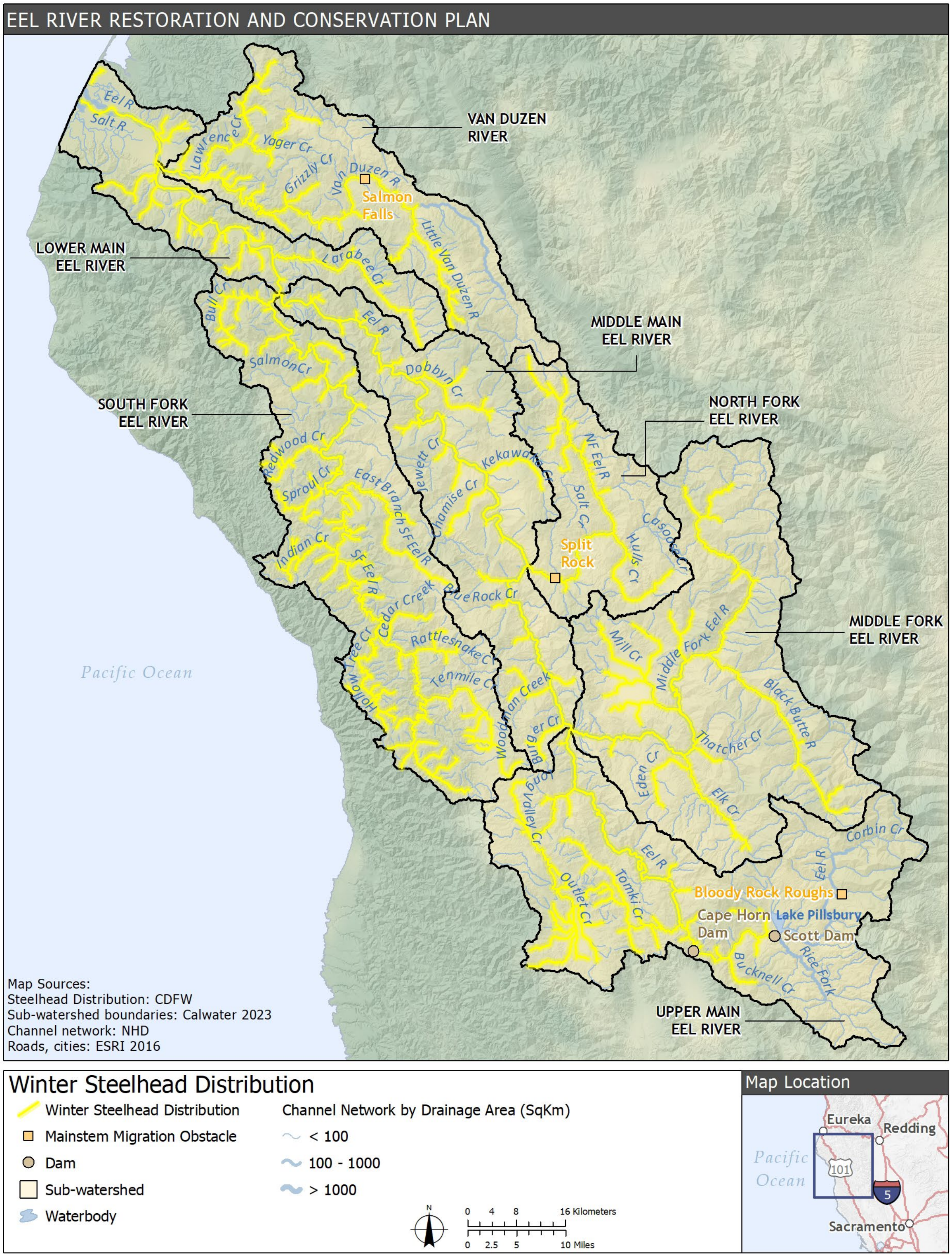

Figure D-3. Suspected distribution of winter-run steelhead in the Eel River watershed.

Figure D-4. Suspected distribution of summer-run steelhead in the Eel River watershed.

3.2.1 Winter-run steelhead

Steelhead typically utilize a greater portion of a watershed's stream network than do Chinook or Coho Salmon, in part due to their greater jumping ability, capacity to navigate to and spawn in higher-gradient channels, and ability to tolerate warmer water temperatures (Roelofs 1983, Barnhart 1991, Trush 1991, Busby et al. 1996). As with other anadromous species, the spawning distribution of steelhead within the watershed is expected to vary between years depending on the timing and magnitude of fall rains, size of the total adult spawning population, and summer stream flows. Likewise, movement between seasonally suitable habitats (e.g., intermittent tributaries or off-channel habitats) may lead to variation in the distribution of rearing juveniles within years.

Systematic watershed-wide surveys for spawning steelhead have not been conducted in the Eel River basin, but available historical information and recent spawning surveys targeting other species indicate that winter-run steelhead are widespread, with spawning populations in all major sub-watersheds (Becker and Reining 2009; CDFW 2014). Figure D-3 illustrates the estimated overall distribution of winter-run steelhead in the Eel River watershed based on spatial data obtained from BIOS. The dataset, generated in 2012, represents stream reaches that are known or believed to be used by winter-run steelhead, but does not necessarily include all streams or the upper extents of channels where the ecotype may be present.

Recent observations of live adult steelhead and carcasses from CDFW spawning surveys conducted from 2010–2021 (Guczek et al. 2020, CDFW unpubl. data, 2010–2021) and various historical observations of juveniles (Becker and Reining 2009, CDFW 2014, CDFW unpubl. data 1939–1941) are generally consistent with the distribution shown in Figure D-3; however, spawning has been documented in several streams not shown, for example, the South Fork Salmon, Dean, and Cahto creeks in the South Fork Eel River sub-watershed. In general, spawning is concentrated in relatively small, lower gradient channels, rather than the mainstems of the major forks or larger tributaries (e.g., the East Branch), though spawning has been documented in a wide range of stream sizes across the watershed (Guczek et al. 2020, CDFW unpubl. data, 2010–2021). As noted above, interannual variation in environmental conditions influences the availability and distribution of suitable spawning habitat.

3.2.2 Summer-run steelhead

The distribution of summer-run steelhead in the Eel River watershed (Figure D-4) is restricted relative to the winter-run, largely due to the relative scarcity of habitat features that support premature migration (see Section 3.2). Suitable over-summer holding habitat exists in streams with predominantly snowmelt-driven hydrology and canyon reaches that contain thermally suitable bedrock pools (i.e., shaded, thermally stratified, or influenced by cold groundwater inputs; Puckett 1975, Busby et al. 1996). While there is some overlap in the distribution of the summer-run and winter-run steelhead, differences in the stream flows during each ecotype's core migration period generally result in spatial segregation, with summer-run steelhead mostly spawning upstream of flow-dependent barriers to migration that are not passable to steelhead in winter (Kannry et al. 2020). This reproductive isolation may reduce gene flow between the two ecotypes, maintaining the prevalence of the genetic markers associated with premature migration in summer-run populations.

Genetically distinct summer-run populations currently persist in the upper reaches of the Middle Fork Eel and Van Duzen rivers and some of their tributaries (Kannry et al. 2020). Genetic evidence and anecdotal historical accounts suggest the distribution of the summer-run ecotype in the larger watershed has contracted in recent decades (Moyle 2002, Yoshiyama and Moyle 2010, CDFW 2019, Kannry et al. 2020). While summer-run steelhead were observed in the North Fork Eel River downstream of Split Rock in the 1990s, the population may have since been extirpated (Yoshiyama and Moyle 2010, CDFW 2019). Summer-run steelhead also historically spawned in thermally suitable reaches of the upper mainstem Eel River prior to the construction of Scott Dam, and the allele associated with premature migration (called "GREB 1L") is still maintained in the remnant resident Rainbow Trout population. In contrast, while there are some historical accounts of adult steelhead over-summering in the South Fork Eel River prior to major floods in the mid-20th century (Jones 1992, Kannry et al. 2020), steelhead in the South Fork Eel River do not currently exhibit premature migration or carry the GREB 1L allele (Kannry et al. 2020). Portions of the upper South Fork Eel River appear to contain suitable adult over-summer holding habitat needed to support the summer-run ecotype but lack the steep, boulder roughs or waterfalls that typically segregate winter-run and summer-run steelhead in the other Eel River sub-watersheds (Trush 1991, Kannry et al. 2020). The headwaters of the South Fork Eel River also have minimal winter snowpack and less-consistent spring flows relative to other streams where summer-run steelhead occur (Kannry et al. 2020). Lack of observation of the summer-run ecotype during historical adult salmonid counts at Benbow Dam (CDFW unpubl. data 1939–1941) further suggests that the ecotype was either not historically present, or at least extremely rare, in the sub-watershed. Summer-run steelhead may have also once spawned in Larabee Creek, Black Butte Creek, and Woodman Creek, but these sub-populations have also likely been extirpated (Jones 1992, Moyle 2002). There are various other tributaries where adult holding and spawning could occur, or historically occurred, and many more where non-natal rearing could occur that are not shown in Figure D-4.

3.2.3 Resident Rainbow Trout

Rainbow Trout are likely the most widespread in the Eel River but are not always distinguished or noted separately from the other two ecotypes. For this reason, there is not a separate distribution map for Rainbow Trout. Patterns in the prevalence of residency varies greatly between watersheds and over time, reflecting complex interactions between genetic and environmental factors that influence whether individuals smolt or remain as residents (Satterthwaite et al. 2009, Sloat and Reeves 2014, Kendall et al. 2014, Kelson et al. 2020). Residency is often presumed to be more prevalent in locations where anadromy is not a viable life-history strategy, such as above impassable barriers to migration (Moyle et al. 2017). Indeed, resident Rainbow Trout populations persist upstream of man-made barriers in the Eel River watershed that restrict access to historical steelhead spawning habitat, such as Scott Dam. However, recent evidence also suggests that resident Rainbow Trout are widely distributed throughout the larger watershed downstream of such barriers (Harvey et al. 2021). Further, resident females appear to make substantial contributions to the persistence of anadromous population components (Harvey et al. 2021).

3.3 Ecology, Life-history, and Habitat Needs

3.3.1 Life-history Timing Overview

O. mykiss spend the most time in freshwater of the salmonid species in the Eel River, with juvenile steelhead rearing year-round and resident Rainbow Trout remaining in freshwater throughout their lives (Table D-3). Critical periods of movement (i.e., down- and upstream migrations) for steelhead tend to coincide with periods of elevated streamflow, albeit at different times of year depending on ecotype and life stage.

The generalized life-history timing for each steelhead ecotype and life stage in the Eel River watershed is presented in Table D-3. This information is based primarily on observations from the watershed but also includes references to other watersheds where more extensive monitoring has been conducted. A more detailed description of each life stage and its timing is provided below.

Table D-3. Generalized life-history timing of steelhead runs in the South Fork Eel River watershed.

Life stage		Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Winter-run	Adult migration[1,2,3]	Peak	Peak	Peak	Span	Span						Span	Span
	Spawning[2,3,4]	Peak	Peak	Peak	Span	Span							Span
Summer-run	Adult migration[4,5,6]			Span	Peak	Peak	Span						
	Holding[6,7,8]						Span	Span	Span	Span	Span		
	Spawning[6,7,8]	Peak	Peak	Peak	Span								Span
Fall-run	Adult entry and holding in lower mainstem[7,9,10]							Span	Span	Span	Span		
	Upstream movement & spawning[11]	Peak	Peak	Peak	Span						Span	Span	Span
Adult post-spawn outmigration (kelt)[1,12]			Span	Peak	Peak	Span	Span						
Half-pounder residence[5, 13]		Span	Span	Span				Span	Span	Span	Span	Span	Span
Incubation[8,15,16,17]		Span	Span	Span	Span	Span	Span						Span
Fry emergence				Span	Span	Span	Span						
Juvenile rearing[8,15]		Span	Span	Span	Span	Span	Span	Span	Span	Span	Span	Span	Span
Juvenile redistribution[16,17,18]								Peak	Span	Span	Peak	Peak	Span
Smolt outmigration[16,17,18,19,20]			Span	Span	Peak	Peak	Peak	Span	Span				

= Span of activity
= Peak of activity

[1] CDFG unpubl. Benbow Dam adult count data, 1938–1976
[2] Guczek et al. (2020); CDFW unpubl. data, 2010–2021
[3] Trush (1991)
[4] Busby et al. (1996)
[5] Everest (1973)
[6] Moyle et al. (2017)
[7] Roelofs (1983)
[8] Barnhart (1991)
[9] Kajtaniak and Gruver (2020)
[10] Hodge et al. (2014)
[11] Roelofs et al. (1993)
[12] Teo et al. (2013)
[13] (Kesner and Barnhart 1972)
[14] Murphy and Dewitt (1951)
[15] Shapovalov and Taft (1954)
[16] MRC (2002)
[17] Vaughn (2005)
[18] Kelson and Carlson (2019)
[19] Maahs (1995)
[20] CDFG unpubl. Benbow Dam outmigrant trapping data, 1939

3.3.2 Adult Migration

Adult steelhead begin spawning migrations after a period of feeding and growth in the ocean that can last several years. Adult winter-run steelhead in the Eel River migrate upstream in the winter and spring during California's "wet season". Summer-run steelhead in northern California enter freshwater and migrate upstream as sexually immature adults in spring and early summer, typically during the snow melt period between April and late June (Everest 1973, Busby et al. 1996, Moyle et al. 2017) (Table D-3). After migrating into cool headwater reaches, summer-run steelhead spend the summer and early fall holding in deep, thermally suitable pools (Everest 1973, Roelofs 1983, Barnhart 1991, Moyle et al. 2017). Summer-run steelhead are thought to leave holding pools and migrate into spawning streams during periods of elevated streamflow caused by late fall and winter rain events (Everest 1973). Fall-run adults enter the lower mainstem from mid-summer through early fall (Roelofs 1983, Hopelain 1998). The arrival of apparent fall-run individuals often coincides with the presence of "half-pounders" in the Eel River estuary and lower mainstem. These individuals generally stage downstream of the Van Duzen River and move upstream after the arrival of fall freshets. Potential relationships between the fall-run component and other ecotypes are poorly understood. However, based on information gleaned from other watersheds with a fall-run such as the Klamath River, adults are thought to be sexually immature upon entry to freshwater, and therefore may be related to the summer-run.

Kelt, or post-spawned adults, generally tend to migrate downstream to the ocean relatively rapidly after spawning (Teo et al. 2013, Moyle et al. 2017). In spawning tributaries to the upper South Fork Eel River, Trush (1991) found that individual winter steelhead typically entered, spawned, and moved back downstream within 1–2 weeks, with males remaining longer than females. Historical observations from the Benbow Dam fish counting station indicated kelts moved downstream through the mainstem South Fork Eel River between early February and mid-June, with apparent peak movement in March and April (CDFG unpubl. data, 1938–1976). Notably, in several years, approximately 1,000 kelts were observed just above the dam in March.

3.3.3 Spawning and Incubation

Despite entering freshwater at different times of year and at varying stages of sexual maturity, winter-run, summer-run, and fall-run steelhead all generally spawn between December and May, with peak spawning typically occurring from January through March (Busby et al. 1996; Guczek et al. 2020; CDFW unpubl. data, 2010–2021). In general, steelhead spawn primarily in tributary streams, many of which are perennial, though some of which become intermittent or go dry in the summer (Everest 1973). This is particularly true of tributaries in the Middle Fork sub-watershed. Mainstem spawning has been observed in years when tributary access is restricted due to lack of winter and spring storm events (Trush 1991). All steelhead ecotypes are capable of spawning multiple times throughout their lives and repeat spawners have been identified in the South Fork Eel River, Middle Fork Eel, and Van Duzen River sub-watersheds (Puckett 1975, Trush 1991). However, the precise incidence of repeat spawning varies between watersheds and has not been thoroughly investigated in the Eel River.

Resident Rainbow Trout in coastal California streams also spawn in the spring, between February and June (Moyle 2017). Resident adults will readily interbreed with anadromous adults and can produce both anadromous and resident offspring (Harvey et al. 2021). The age and corresponding size at which resident Rainbow Trout spawn depends on local growth potential (Moyle 2002) and has not been described for populations in the Eel River. In general, coastal Rainbow Trout mature by age two or three and may spawn multiple times throughout their lives (Moyle 2017).

Steelhead eggs incubate in redds for 3–14 weeks after fertilization, depending on water temperatures (Shapovalov and Taft 1954, Barnhart 1991). After hatching, alevins remain in the gravel for an additional 2–5 weeks while absorbing their yolk sacs, and then emerge in spring or early summer (Barnhart 1991). Based on the timing of spawning, the typical incubation period, and when newly emerged fry have been captured during outmigrant trapping, developing steelhead eggs or alevin may be present in spawning gravels from approximately December through June (MRC 2002, Vaughn 2005).

3.3.4 Juvenile Rearing and Outmigration

Juvenile steelhead in the Eel River basin display a diversity of life-history strategies and movement patterns, with multiple age classes utilizing a variety of habitats in cool headwater spawning tributaries, non-natal tributaries, mainstem corridors, and the estuary (Puckett 1977, Nielson et al. 1994, Kelson and Carlson 2019, Kelson et al. 2020, Georgakakos 2020, Wang et al. 2020). The full array of juvenile steelhead life-history strategies and their relative prevalence across space and time has not been empirically described.

After emerging from spawning gravels, steelhead fry generally occupy shallow, low-velocity habitats such as stream margins or off-channel habitats (Hartman 1965). As fry grow and improve their swimming ability throughout the summer and fall, they are increasingly associated with faster water velocities and deeper habitats that contain cover such as cobble and boulders (Hartman 1965, Everest and Chapman 1972).

Juvenile steelhead require cool water temperatures to grow and survive. While they can withstand brief periods of exposure to higher temperatures (particularly when sufficient food resources are available), juvenile steelhead generally require maximum weekly average water temperatures below 22°C (North Coast Regional Water Quality Control Board 2010).

Juvenile steelhead in northern California spend 1–3 years rearing in streams and estuaries before emigrating to the ocean. Age at emigration varies by location and is largely driven by environmental conditions that influence growth rate in early life (Brown 1990, Hopelain 1998, Kendall et al. 2015, Moyle et al. 2017, Kelson and Carlson 2020). For example, in the upper mainstem sub-watershed, individuals can rear in tributaries for 2 or 3 years before emigrating, whereas individuals rearing in the mainstem Eel River below Scott Dam may emigrate after a single year due to enhanced growth conditions (SEC 1998). Similarly, analyses of scales collected from adult summer-run steelhead suggests most individuals in the Van Duzen emigrated after rearing for single year, whereas juveniles in the Middle Fork Eel River reared for 1–3 years before emigrating (Puckett 1995), and juvenile winter-run steelhead in the South Fork Eel River typically reared in freshwater for 2 years (Trush 1991).

3.3.5 Smolt Outmigration

Salmonid smolt outmigrant trapping data from the Upper Eel River indicate that steelhead smolt outmigration generally occurs from March through mid-June and peaks in April and May (VTN 1982, Beak Consultants Inc., 1986, SEC 1998). Outmigrant monitoring conducted in the spring and early summer in tributaries to the South Fork Eel River has documented downstream movement of both age-0 (young-of-the-year) and age-1+ steelhead (Puckett 1976, Maahs 1995, PCFFA 1988, MRC 2002, Vaughn 2005, Kelson and Carlson 2019). Based on available length data, many of the age-0 individuals captured had recently emerged from redd gravels and were likely redistributing from upstream spawning areas to larger tributary channels or mainstem habitats. The age-1 and older component included age-1 juveniles that were moving downstream, potentially to rear in the mainstem, non-natal tributaries, or the estuary, and larger age-2 juveniles beginning to smolt and migrate to the ocean.

While most downstream movement of juvenile steelhead appears to occur in the spring and summer, they may move throughout the year (Puckett 1976, Brown 1990, Roelofs et al. 1993). In one year, Kelson and Carlson (2019) documented smaller numbers of juvenile steelhead moving downstream in Elder Creek (tributary to the South Fork Eel River) after pulse-flow events in the fall, a period not typically included in other outmigrant monitoring efforts. Non-spring movements of juvenile steelhead in the watershed warrant additional research due to the potential role of these life-history variants in increasing population resiliency.

Available evidence suggests that juvenile steelhead downstream movements through the mainstem South Fork Eel River (CDFG unpubl. data, 1939; Roelofs et al. 1993) likely peak approximately 1–3 months after emigration from tributaries (Maahs 1995, MRC 2002, Vaughn 2005, Kelson and Carlson 2019), indicating that a portion of the juvenile population likely spends up to several months rearing in the mainstem after leaving tributaries. Limited mainstem trapping from Benbow Dam in 1939 documented downstream movement of juvenile steelhead (primary age-1 and older) in the mainstem South Fork Eel River from the initiation of trapping in early April through mid-August (CDFG unpubl. data, 1939). Peak capture at Benbow was in June, with over 75% of annual captures by late-June and 90% by mid-July. Notably, however, there was a significant gap in trapping from May 18–25. A subset of juvenile steelhead captured at Benbow Dam were measured in late April and again in late July (CDFG unpubl. data, 1939). Late April lengths ranged from approximately 75–185 mm and most individuals were >120 mm, indicating the early component of the trapped population were primarily age-1 or older. Late July lengths ranged from 50–250 mm, indicating the likely presence of age-0, age-1, and age-2 individuals in the catch. More recent mainstem outmigrant trapping conducted at multiple sites in the vicinity of Benbow in 1993 (a year with relatively high flows and low water temperatures) found considerable movement of age-0 steelhead in the mainstem through July and age-1 and older steelhead through August (Roelofs et al. 1993).

After leaving the tributaries and mainstems in the major sub-watersheds, juvenile steelhead utilize the lower Eel River and estuary as transitional habitat between freshwater and saltwater (Puckett 1977, Cannata and Hassler 1995). Historical sampling indicates that juvenile steelhead were abundant in the Eel River estuary from mid-May through mid-July (Murphy and De Witt 1951). During sampling conducted at sites in the Eel River estuary throughout the 1974 water year, Puckett (1977) captured juvenile steelhead during all months and at numerous sites across the estuary. Subsequent sampling by Cannata and Hassler (1995) indicated greatest utilization of the estuary by juvenile steelhead during the summer and early fall months. Multiple age classes (age-0, age-1, and age-2) of juvenile steelhead were documented utilizing portions of the estuary for rearing, but age-0 and age-1 were present during the most months (Puckett 1977). Duration and spatial distribution of estuary utilization by juvenile steelhead requires additional research due to the importance of this part of the watershed for the South Fork Eel River steelhead population.

3.3.6 Ocean Residence

Steelhead in Northern California typically spend 1–3 years in the ocean before spawning for the first time (Moyle 2002), with most individuals first spawning after 2 years in salt water. This pattern appears to hold true in the Eel River watershed; scale samples collected from adult winter-run steelhead in the South Fork Eel River (Beach 1972 as cited in Trush 1991) and summer-run steelhead in the Van Duzen and Middle Fork Eel rivers (Puckett 1975) suggest most individuals spent 1 or 2 years in the ocean before spawning, while very few spent three years in the ocean. Several of the fish sampled in each population were repeat spawners, having spent one or more additional years in the ocean between spawning migrations.

3.4 Life-history Diversity Conceptual Model

O. mykiss display extensive diversity in movement timing and habitat use as both juveniles and adults. Here, we catalogue the diversity of juvenile and adult strategies separately, to highlight diversity in spatial and temporal use of habitats throughout the watershed in each life stage. Even though they are separated here, we acknowledge that adult strategies influence juvenile strategies, as the timing and location of spawning influences incubation length, emergence timing, and early life-history growth potential.

3.4.1 Adult Life-history Strategies

As described in Section 3.2, adult steelhead in the Eel River watershed exhibit several distinct life-history strategies (also referred to as ecotypes or run-times) that vary in the seasonal timing of arrival to freshwater and coincident state of gonadal development. Within these fundamental strategies there is considerable variation between individuals in age at return to freshwater and propensity to outmigrate and spawn again in subsequent years. While the role that genetics plays in influencing some facets of this variation is relatively well understood (e.g., predisposition towards premature migration, natal homing behavior, etc.), other linkages—such as the relationship between the half-pounder life-history variant and seasonal timing of return to freshwater—may exist but have not yet been well described. In general, genetically ingrained predispositions for run-timing interact with interannual hydrologic variation to influence the distribution of holding and spawning locations utilized by individuals each year, which in turn impacts fry emergence location and may influence juvenile growth, survival, and the expression of early life-history strategies.

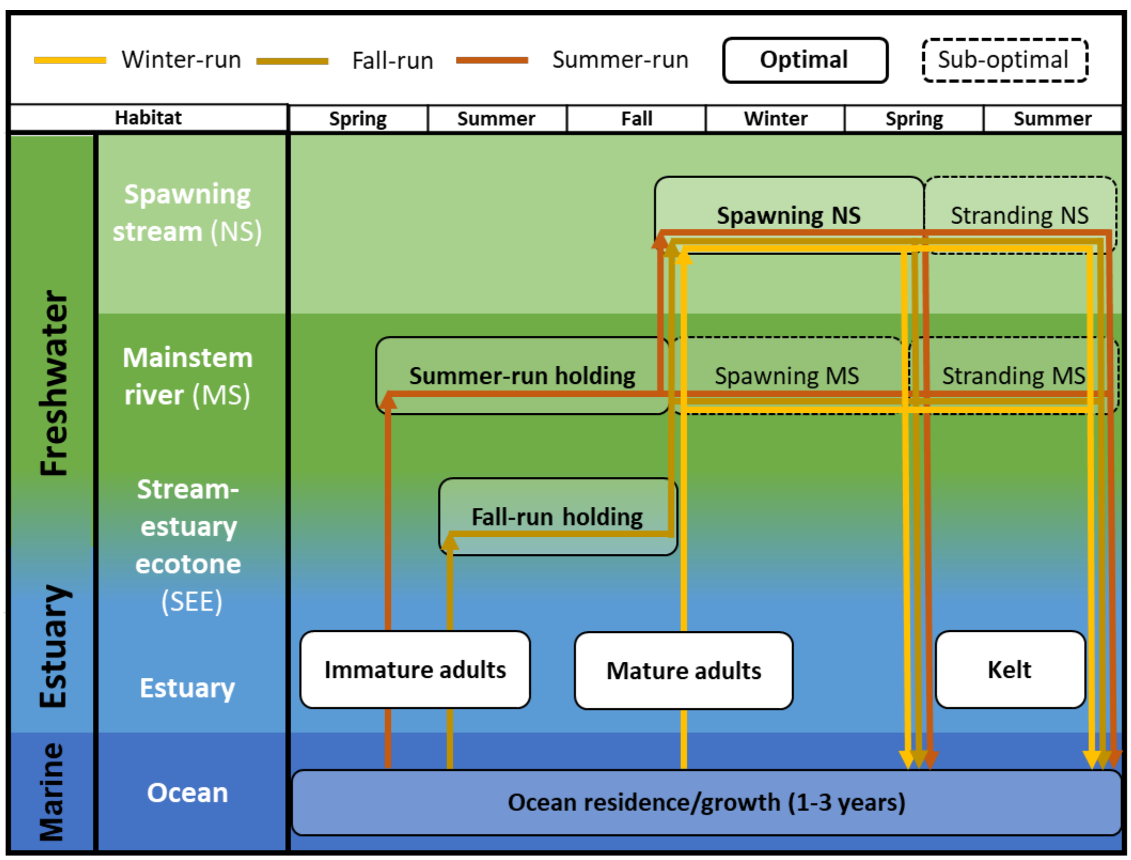

Figure D-5. Diversity in adult life-history strategies and run timing in *O. mykiss*.

3.4.1.1 Fall-run

Because the mouth of the mainstem Eel River remains open year-round, adult fall-run steelhead can enter the estuary and lower Eel River when relatively low baseflows in the mainstem may restrict upstream movement. Certain riffles in the lower Eel River may be too shallow for adults to successfully navigate at typical dry season baseflows, a phenomenon that has described in the watershed for adult fall-run Chinook salmon (CDFG, unpubl. data, 1938–1976). Similar interruptions to upstream movement by steelhead have also been documented at riffles in the upper Eel River (VTN 1982, SEC 1998). As described above, more recent sonar-based estimates of migration timing in the South Fork Eel River are generally consistent with this pattern (Metheny 2020a).

When riffle crest depths in the lower mainstem are sufficient to permit passage, adult fall-run steelhead may continue migrating upstream into the upper Eel and other sub-watersheds. However, because brief fall freshets may produce such conditions before the onset of the true wet season, fall-run adults may encounter additional flow-dependent impediments to movement further upstream, for example in the South Fork Eel River above Rattlesnake Creek (Trush 1991) or in the upper Eel River at Hearst Riffle (VTN 1982).

It is not clear whether fall-run steelhead enter freshwater in a state of sexual maturity, or whether they must undergo some reproductive development while holding in the lower river or potentially further upstream. Because the fall-run adult migration period partially overlaps with the winter-run migration period, it is difficult to draw precise conclusions about spawning ecology. For example, it is unclear whether spawning adult fall-run or winter-run intermix or remain spatially or temporally segregated through some undescribed mechanism. Still, it is likely that fall-run and winter-run spawn in similar habitats. In low water years, adults may not be able to access upper spawning tributaries. Under such circumstances, adults may spawn in less optimal locations—such as the mainstems of larger tributaries or the major forks—where suitable spawning habitat exists. Such locations may not be as conducive to egg incubation or development of alevin, thus hydrologic conditions have the potential to influence reproductive success. The timing, duration, and ultimate success of each migration and spawning effort is therefore influenced by the coincident hydrological conditions each year. Reproductive success is likely maximized in wet years when elevated streamflow facilitates movement past critical riffles in the lower mainstem and entry into spawning tributaries for extended periods, increasing the area of suitable spawning habitat available to spawning adults.

As described above, adult steelhead may return to freshwater to spawn for the first time after spending between 1 and 3 years in saltwater, with 2 years being most common. Furthermore, adults that spawn repeatedly may spend several additional years in saltwater. In general, older individuals tend to be larger, and there is a positive correlation between female body size and the number of eggs produced during a spawning event. Thus, individuals that spend more time growing in saltwater may experience increased reproductive fitness. By spawning repeatedly (at a larger body size in each subsequent spawning year), females may enjoy increased lifetime fecundity. Outmigration by kelt is likely maximized in wet years with prolonged elevated spring streamflow.

3.4.1.2 Winter-run

As described in Section 3.2.2., adult winter-run steelhead migrate upstream during the wet season, when baseflows throughout the watershed tend to facilitate upstream movement except in the driest years. Historical fish counts at Benbow Dam on the South Fork Eel River indicate that the first migrating adult steelhead typically arrived at that location from mid- to late November while the last individuals typically arrived between late April and early May (CDFW unpubl. data 1939–1941). Historical fish counts conducted at the Cape Horn Dam fish latter at the Van Arsdale Fisheries Station (VAFS) reveal a similar pattern in the upper mainstem Eel River, with the first adult steelhead arriving in November, the last arriving in May, and peak movement occurring between January and March (VTN 1982). More recent sonar counts of adult salmonids in the lower South Fork Eel River are generally consistent with movement patterns observed at Benbow Dam and VAFS (Metheny 2020).

As with fall- and summer-run steelhead, interannual variation in hydrologic conditions influences the ability of adult winter-run steelhead to access and utilize spawning habitat in some tributaries. Access to these spawning locations may be restricted in low water years as described by Trush (1991), and adults may spawn in the mainstems of the major forks or higher-order tributaries under such conditions, where suitable spawning habitat exists. Spawning distribution extent, reproductive success, and the probability of successful kelt outmigration are also likely maximized in wet years as described above.

3.4.1.3 Summer-run

As described in Section 3.2.2, adult summer-run steelhead migrate upstream in the Eel River watershed during spring and early summer. These individuals depend on moderate spring flows—often driven by snowmelt runoff—to navigate past flow-dependent barriers and reach over-summer holding habitat. Historical fish counts conducted in the mainstem Eel and Van Duzen rivers, and creel surveys conducted in the Middle Fork Eel River detected migrating summer-run adults between April and June (Puckett 1975). In springs following winters with low snowpack, summer-run steelhead may not be able to successfully reach holding areas. If no suitable holding habitat exists downstream of flow-dependent barriers, it is not clear whether some summer-run adults forego spawning and return to the ocean, or if they perish before spawning. Additionally, In years where they can reach holding areas but following fall/winter flows are low, may spawn in sub optimal locations.

As described in Section 3.1.2, summer-run populations likely only persist in stream systems with regularly accessible habitats that support over-summer holding, such as pools that remain thermally suitable through the dry season. Extreme deviations from typical summer water conditions (i.e., very low streamflow and resultant hydrologic disconnection that degrades water quality, or alterations to typical patterns of thermal stratification in bedrock pools) may render such habitats unsuitable and could threaten the viability of summer-run populations in the long term.

Adults typically move from holding areas into spawning reaches upon the arrival of rainstorms during the wet season. Delayed onset of the wet season may prolong the duration of the over-summer holding period or force steelhead to utilize sub-optimal spawning habitat closer to holding areas (i.e., in mainstems), which could increase pre-spawn mortality or reduce reproductive success. California's wet season is predicted to "sharpen" in coming decades, with proportionally less rain falling in fall and spring (Swain et al. 2018). Such changes could reduce the spatial extent of habitats that support summer-run populations, further restricting the distribution of the ecotype.

3.4.2 Juvenile Life-history Strategies

3.4.2.1 Overview

Juvenile *O. mykiss* display a dizzying number of life-history strategies, and pathways within each strategy, with the ability to move between natal and non-natal rearing habitats in freshwater and spend varying amounts of time in freshwater before smolting or maturing in freshwater (residency). We organized the juvenile life-history strategies into 3 main groups with increasing amount of time spent in freshwater: residency, age-2 smolt, and age-1 smolt (Figure D-6). Each of these strategies have the potential to move into non-natal habitats, and back into natal streams, in the freshwater rearing stage. The time points at which redistribution is most common are the spring, accompanying the flow recession, and the fall, following the first rains (Kelson and Carlson 2019). As such, our second tier of organization is *where* juveniles spend the dry vs. wet season, with options including the natal stream, a mainstem, a non-natal stream, or the estuary (Figure X). Additionally, the half-pounder strategy was historically common (Snyder 1925) and is still present in smaller numbers in the Eel River, and this 4–5 month foray into fresh water in the fall/winter is associated with both age-1 and age-2 smolts (Peterson 2011, Hopelain 1998) (Figure X). Finally, we note that other ages at smoltification are possible, but rarely documented, historically, or currently, in *O. mykiss,* including age-0 smolts and age-3 smolts. Age-0 smolts would be most likely to occur in extremely high growth years, while age-3 smolts would be most likely to occur in a series of low-growth years. Age-3 smolts would face the same decision matrix in their final year in freshwater as in the first two, so we excluded them from the diagram for simplicity.

The total number of possible strategies, combining age at out-migration and habitat use in the wet vs dry season, is too many to discuss individually, so we highlight below the strategies that are predicted to be most likely to occur, or occur historically, in the Eel River. Piecing together the life-history strategies that occur (or occurred) in the Eel River was an act of detective work, piecing together various information on when fish move and when/where they are found. We recommend that future monitoring better capture the diversity of juvenile strategies and their potential to contribute to adult runs throughout changing environmental conditions (Section 3.5.3).

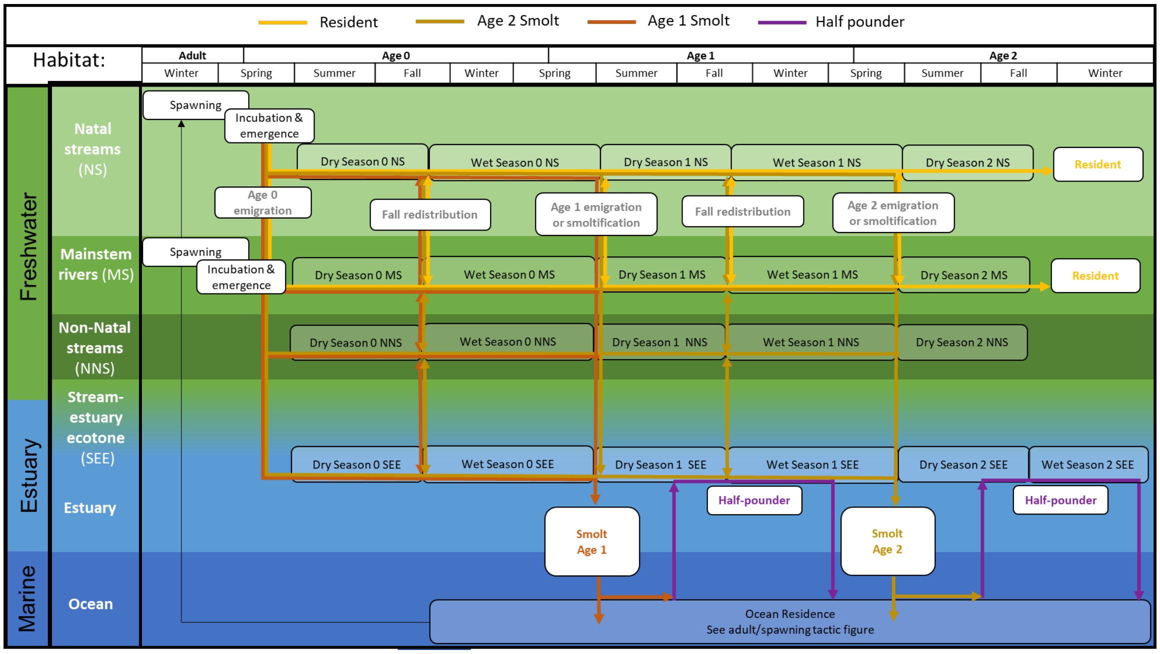

Figure D-6. Diagram demonstrating the spatial and temporal use of different habitats by juvenile *O. mykiss* in the Eel River, organized by age at smoltification and location in the dry vs. wet season.

3.4.2.2 Spotlight strategy – Resident, natal-rearing

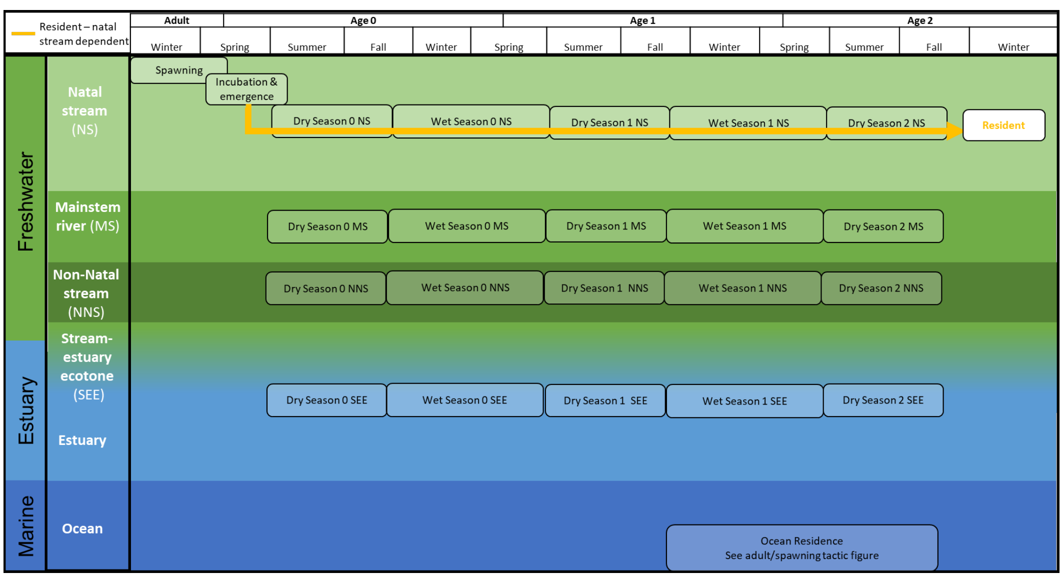

Figure D-7. Diagram showing the pathway of resident, natal-rearing juvenile *O. mykiss*.

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3.4.2.3 Spotlight life-history strategy – Age-2 smolt, mainstem rearing

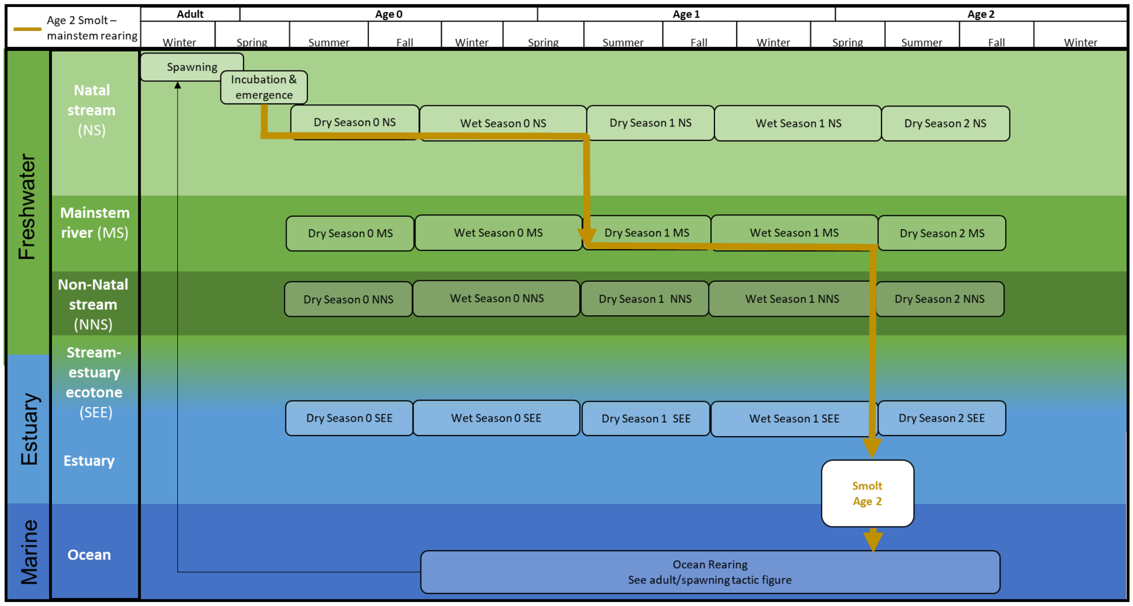

Figure D-8. Diagram showing the pathway of Age-2 smolt, mainstem-rearing *O. mykiss*.

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3.4.2.4 Spotlight strategy – Age-2 smolt with estuary rearing

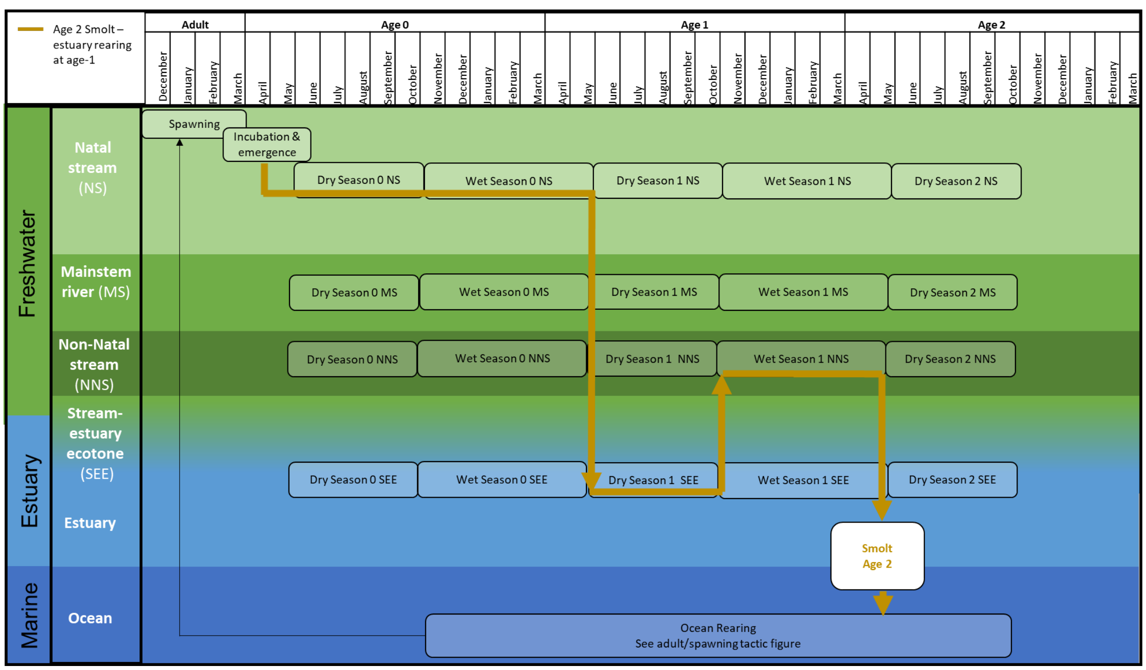
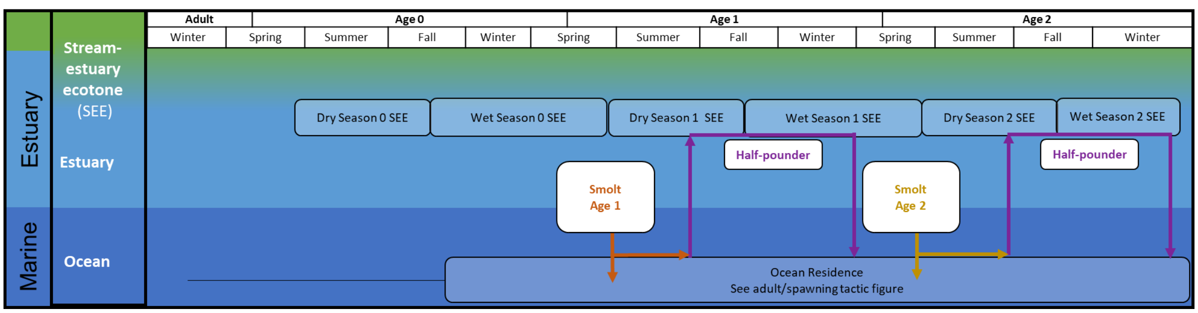


Figure D-9. Diagram showing the pathway of Age-2 smolt, estuary-rearing *O. mykiss*.

Similar to the previous strategy, in this strategy, *O. mykiss* leave their natal stream in the spring as age-1 juveniles. They move to the stream-estuary ecotone for the summer to take advantage of productive rearing habitats. Juvenile *O. mykiss* have been observed rearing in the Eel River estuary (Pucket 1976, 1977, Cannata 1994-95). In Mediterranean-climate rivers, summer-fall estuary rearing has the potential to be an extremely high growth habitat (0.2-.8% of growth per day), compared to up-river growth (0.1% per day), when stream flows are at their annual low (Hayes et al 2008). In Scott Creek in southern California, the majority of returning adults spent some time rearing in the estuary (Hayes et al 2008), and the largest smolts are ones that spent some time estuary rearing (Hayes et al 2011), suggesting that this strategy may contribute disproportionately to adult returns if the estuary is in good condition. However, in estuaries further north, such as the Columbia River estuary, juvenile steelhead tend to pass quickly through the estuary, without rearing for as long as other salmonid species (Weitkamp et al 2012), moving quickly to nearshore coastal areas (Daly et al 2014). Given that juvenile steelhead have been found in the estuary year-round in the modern era (CDFW 2010), and especially in the summer and fall, which is outside of the ocean-migrating time, it is likely that the estuary was historically used as a rearing habitat. Understanding factors that currently limit estuary-rearing will help revive a high-growth habitat that contributes greatly to population recovery and resilience.

While the estuary may be a high growth environment in the summer, it can become a seasonally harsh environment due to warming temperatures and higher velocities in the winter. In Scott Creek, many juvenile steelhead retreat upstream into freshwater for the winter as the estuary becomes too warm (Hayes et al 2011). In the Eel River, it is likely that juvenile steelhead may seek out nearby velocity refugia in the winter. They may move into non-natal streams that are near the estuary, such as the Salt River, or further upstream, until migrating through the estuary again the following spring.

3.4.2.5 Spotlight strategy – Half-pounder



The half-pounder migration is a unique strategy where immature *O. mykiss* re-enter freshwater in the late summer/fall (August – November), after only 3–5 months in the ocean, then and return to the ocean the following spring (Kesner and Barnhart 1972). This this life-history strategy occurs primarily in streams in southern Oregon and northern California coastal, including the Eel, Klamath and Rogue rivers (Everest 1973). Half-pounders are typically 25–45 cm in fork length and remain in the lower reaches of the river (Murphy and De Witt 1951), but there are observations of half-pounders as far upriver as the South Fork Eel River and at the Van Arsdale trap. Both sexes have been observed equally in half-pounder migrations. Kesner and Barnhart (1972) noted that growth during the half-pounder migration is low, even though they are feeding, with fish typically only growing 1 cm in length, while a 15 cm length gain is typical for the same period in the ocean (McPherson and Cramer 1982). However, the run timing mirrors that of historic Chinook runs, so it is possible that growth rates were higher when Chinook eggs were available as a food source. Peterson (2011) found that the half-pounder strategy was more common for smolts that entered the ocean at age-1, but also occurred for age-2 and age-3 fish in the Trinity River. Additionally, juveniles that were smaller for their age when exiting the estuary where more likely to undergo a half-pounder migration. These patterns together, with smaller juveniles re-entering the freshwater, only to lose out on high-growth opportunities in the ocean, suggest that the benefit of the half-pounder migration strategy is likely increased survival rates (Satterthwaite 1988). Hodge et al (2014) estimated through life cycle models that that first-year ocean survival is 21-40% higher for half-pounder phenotypes, but their fitness is 17-28% lower due to smaller body size and reduced fecundity.

The half-pounder migration is thought to be most closely associated with the summer-run adult migration timing, but also occurs in the fall-run and winter-run (Everest 1973, Hodge et al 2014, Peterson et al 2017). In the Rogue River, Everest (1973) found that 97% of summer-run adults completed a half-pounder migration before their spawning migration, whereas only 21% of winter run adults make a half-pounder migration (McPherson and Cramer 1982). Hopelain (1988) also noted that the half-pounder migration was more common in the summer run in the Klamath River and its tributaries.

The half-pounder strategy was likely historically a strategy that provided population resilience during years when ocean conditions were poor. Ocean survival for steelhead in the Pacific Northwest has been declining since 1980 (Kendall et al. 2016). Climate change may continue to provide bioenergetically challenging conditions for ocean survival as anomalously warm years become more normal. For example, the warm “Blob” in 2015-2016 altered prey resources for ocean steelhead and contributed to lower body condition (Thalmann et al 2020). Restoring a half-pounder migration would restore one strategy that relies less heavily on ocean conditions. Notably, restoring the half-pounder phenotype may require restoring conditions that allow for persistence of summer-run steelhead given the correlation between the two.

3.5 Conceptual Model Outcomes

3.5.1 Common Stressors Across Life cycle and Life-history Strategies

TO BE PROVIDED FOR FINAL

3.5.2 Restoration Take-home Points

TO BE PROVIDED FOR FINAL

3.5.3 Data Gaps and Research and Monitoring Needs

Data gaps and research questions include:

- Connection between half-pounder strategy and summer-run steelhead
- Connection between fall-run and summer-run steelhead
- Distribution of spawning by fall-run (e.g., spatially segregated from winter-run? If no, how is the behavior maintained with gene flow from winter-run?)
- Connection between half-pounder and propensity for repeat spawning
- Understanding the viability/occurrence of a mainstem-rearing resident strategy throughout the basin

Monitoring recommendations include:

- Monitor size, age, timing, and origin of fish that are moving downstream in the Spring (including smolts) at several mainstem locations (rotary screw traps, acoustics tags)
- Monitor estuary use of *O. mykiss* throughout the year (monthly seines or estuary sampling events)

- Monitor timing of movement from lower river into the estuary, and size/age of fish that are moving between the two ecotones.
- Monitor juvenile movement into/out of seasonally suitable rearing habitats
- Monitor over-wintering locations of juvenile rearing *O. mykiss* (snorkel surveys in tributaries)
- Conduct a study of otolith microchemistry to identify prevalence of rearing strategies
- Conduct adult scale analysis to better understand population age structure
- Monitor adult escapement and spawning
- Genetic composition/relatedness between fall-run and summer/winter-run?
- Genetic markers unique to fall-run
- Fall-run spawning distribution.

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4 PACIFIC LAMPREY – TO BE PROVIDED FOR FINAL

4.1 Population Status

4.2 Distribution

4.3 Ecology, Life-history, and Habitat Needs

4.4 Life-history Diversity Conceptual Model

4.5 Conceptual Model Outcomes

4.6 References (Pacific Lamprey)

5 GREEN STURGEON – TO BE PROVIDED FOR FINAL

5.1 Population Status

5.2 Distribution

5.3 Ecology, Life-history, and Habitat Needs

5.4 Life-history Diversity Conceptual Model

5.5 Conceptual Model Outcomes

5.6 References (Green Sturgeon)

Appendix E

Tiered Goals and Objectives

NOTE TO REVIEWERS:
This draft appendix is an in-process work product.

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Table E-1. Tiered goals and objectives for fish population category of influence.

	Goals	Sub-Goals	Objectives: *action statement*	Sub-Objectives
Fish Populations	Achieve naturally self-sustaining and harvestable native fish populations	Increase species population sizes	Adult abundance*: Increase the number of successfully spawning adults that return to freshwater*	Increase number of returning adults
				Reduce pre-spawn mortality
				Increase smolt-to-adult survival
			Juvenile abundance*: Increase the number of juveniles that successfully outmigrate to the ocean*	Increase juvenile rearing habitat carrying capacity
				Increase juvenile survival (summer low-flow and winter high-flow)
				Reduce smolt outmigration mortality due to predation
		Increase freshwater productivity of anadromous fish species (e.g., population growth rate, smolts per adult, adults per adult)	Egg-to-fry survival*: Increase embryo and larvae survival rates from their deposition to emergence*	Increase egg-to-fry survival
				Reduce elevated levels of fine sediment in spawning beds
			Fry-to-smolt survival*: Increase survival rates through juvenile life stages*	Increase survival of fry and rearing juveniles in freshwater stage
				Reduce fish mortality due to stranding or entrainment
				Reduce fish mortality due to predation
			Juvenile growth*: Increase the size and health of juveniles that successfully outmigrate to the ocean*	Increase growth of fry and juveniles by inducing favorable changes to food resources.
				Improve rearing habitat and reduce competition
		Restore species distributions to historical extents	Barriers to juvenile and adult migration*: Expand potential for adult and juvenile species distributions*	Restore or mitigate passage at large barriers that block access to historic habitat
				Improve passage conditions, physical and flow, at small barriers or obstacles that discourage movement
				Remove or improve fish passage that prevent access to historically occupied habitats
			Competition and predation: *Suppress or eradicate non-native predatory species and reduce impacts of unnatural interspecies competition*	Increase length of time native fish can use mainstem habitats in summer
				Reduce presence of pikeminnow in summer

	Goals	Sub-Goals	Objectives: *action statement*	Sub-Objectives
Fish Populations (cont.)	Achieve naturally self-sustaining and harvestable native fish populations (cont.)	Maintain and increase diversity of life history tactics	Diversity in juvenile tactics: *Support diversity of juvenile life history tactics by encouraging fish use of diverse habitats throughout the watershed*	Increase spatial distribution of juveniles and diversity of habitat use
				Restore the estuary and nearby habitats for refuge for juvenile rearing and adult holding
				Improve conditions in the mainstem for juvenile rearing
				Improve spawning habitat in streams with diverse over-summering conditions, including mainstems and/or habitats that are more accessible in dry years
				Restore habitats that may be necessary for spawning/rearing in dry years, including lower quality habitat
			Variability in migration timing*: Encourage natural variability in juvenile and adult life history tactics through time*	Extend the time window when juveniles can migrate downstream by creating predator-free mainstems for longer in the spring
				Restore natural flow regimes to allow fish passage
				Extend time window when adults can successfully migrate by removing barriers in the estuary and lower river
			Population gene flow and genetic diversity*: Maintain or restore genetic diversity by encouraging gene flow among sub-populations*	Maintain genetic diversity at neutral alleles for all species
				Increase spatial distribution of early-migration genetic diversity in salmonids (Greb1L/ROCK)
				Maintain diversity at OMY5 in O. mykiss
				Increase spatial distribution of migratory alleles at OMY5 in O. mykiss
				Maintain early vs late maturation genetic diversity in lamprey

Table E-2. Tiered goals and objectives for habitat category of influence.

	Goals	Sub-Goals	Objectives: action	Sub-Objectives
Habitat	Improve quantity, complexity and diversity of habitats within the stream corridor	Increase quantity of suitable habitat for focal species and life stages	Adult holding habitat: *Increase the number and size of early fall holding habitats that have been depleted for returning salmon adults in the lower Eel River and estuary reaches*	Increase deep pools in the lower mainstem Eel River for all species
				Increase deep pools and cover in snowmelt streams for spring-run Chinook and summer-run steelhead
				Increase deep pools and other holding habitat in mainstem reaches
			Spawning habitat quantity: *Increase spawning gravel area by restoring to optimal spawning substrate assortments*	Increase suitable spawning substrate patches and substrate diversity in mainstems
				Increase substrate diversity in sediment-loaded tributaries
				Reduce fine sediment inputs to improve quantity of high-quality spawning habitat
				Increase large flow obstructions to promote substrate sorting and patch diversity
				Increase access to tributaries for spawning
			Wet season rearing habitat: *Increase quantity and diversity of wet season rearing habitats*	Increase off-channel habitats such as alcove/backwaters and off-channel ponds
				Increase floodplain connectivity
				Increase area of in-channel low velocity refuge habitat through large wood augmentation
				Increase clear-water habitats to provide winter and spring foraging opportunities
			Dry season rearing habitat: *Increase extent of cool perennial streams*	Improve currently unsuitable habitats with temperature mitigation, in-channel restoration
				Maintain suitable baseflows to support dry season rearing habitats

	Goals	Sub-Goals	Objectives: action	Sub-Objectives
Habitat (cont.)	Improve quantity, complexity and diversity of habitats within the stream corridor (cont.)	Increase complexity and quality of key habitats	In-channel habitat complexity*: Increase complexity of in-channel habitat features*	Add large wood, boulders, and/or other channel roughening features to increase instream cover and complexity for juvenile summer rearing habitat
				Add large wood and vegetation features to provide cover and shelter during spring-summer recession and base flow periods
				Add large wood, boulders, and/or other channel roughening features to create high flow refuge habitat
				Increase pool depths where pools have filled in, such as on the mainstem
				Restore and increase riparian vegetation to provide cover and wood recruitment
			Habitat sequence diversity*: Restore natural riffle-pool sequencing where conditions have been altered*	Restore and maintain natural balance of riffles and pools
			Thermally suitable conditions and refugia*: Create, expand and enhance cold-water refuge areas and increase accessibility to incorporate current and projected flow regimes*	Increase and protect thermal refugia, especially in warmer tributaries and mainstem rivers
				Increase accessibility to current thermal refugia
			Turbidity: *Restore natural levels of turbidity to improve foraging opportunities for visual feeders and growth for primary production*	Increase access to and amount of clear-water habitats to provide winter and spring foraging opportunities for fish
				Address sources of fine-sediment input

	Goals	Sub-Goals	Objectives: action	Sub-Objectives
Habitat (cont.)	Improve quantity, complexity and diversity of habitats within the stream corridor (cont.)	Restore connectivity between habitats	Lateral Connectivity—connectivity to off-channel and floodplain habitat*: Improve migration pathways for rearing juveniles to access productive winter refuge habitats via tributaries, side-channels and low-lying floodplains*	Remove or lower physical barriers blocking access to off-channel habitats
				Restore sediment and flow regimes to prevent channel incision
				Restore flow regimes to maintain seasonal connectivity to off-channel habitats
			Longitudinal connectivity: *Improve connectivity between tributaries and mainstems, between sub-watersheds and estuary*	Remove barriers (flow and physical) to allow upstream passage of adult migratory species
				Increase access to and passage between diverse rearing habitats, including mainstem and tributaries
				Remove barriers (flow and physical) to allow downstream passage of ocean-migrating juveniles
		Foster productive riverine food webs that support growth of native fishes	Primary productivity: *Create habitats that encourage growth of nutrient-dense and edible epilithic and epiphytic diatoms and natural filamentous algae, and discourage toxic cyanobacteria*	Promote natural growth of nutrient dense filamentous algae, and epilithic and epiphytic diatoms
				Reduce growth of toxic cyanobacteria
			Macroinvertebrates: *Create diversity of habitats through space and time for proliferation of diverse and edible macroinvertebrates*	Support persistence of diverse of benthic macroinvterbrates through habitat, substrate, and flow diversity
				Support persistence of sensitive macroinvertebrates (EPT) through high water quality
				Restore riparian zones to increase input of terrestrial invertebrates
			Non-native aquatic species: *Create habitats that favor native over non-native fishes, active removal when necessary*	Reduce abundance and spatial distribution of pikeminnow
				Reduce other non-native fishes (e.g., catfish, bass) and predators (bullfrog)

	Goals	Sub-Goals	Objectives: action	Sub-Objectives
Habitat (cont.)	Improve quantity, complexity and diversity of habitats within the stream corridor (cont.)	Increase and improve estuarine habitat	Tidal slough network accessibility*: Expand and enhance the inter-tidal slough network to increase capacity across all trophic levels*	Expand and reconnect inter-tidal slough network
				Restore/increase spatial extent of the estuary
				Restore connections to nearby refugia such as small tributaries
			Estuarine and slough channel habitat complexity*: Enhance habitat complexity in slough channels to provide shelter, cover for rearing and foraging juveniles*	Restore salinity regimes in estuary
				Increase habitat complexity through large wood structures or other features
				Restore thermal refugia within estuary
			Estuarine food webs*: Increase estuarine primary production that supports healthy and diverse food web dynamics*	Increase primary production and support diverse macroinvertebrate populations in the estuary
				Increase inundation area/tidal prism to increase primary producers

Table E-3. Tiered goals and objectives for Landscapes category of influence.

	Goals	Sub-Goals	Objectives: action	Sub-Objectives
Landscapes	Protect, enhance, and restore intrinsic physical watershed processes (e.g., hydrologic, geomorphic, and riparian) that create and maintain complex channel morphology and regulate habitat connectivity.	Protect, enhance, and restore functional flow components	Baseflow components: *Protect, maintain, and/or enhance dry-season and wet-season baseflows.*	Reduce dry-season diversions
				Maintain habitat connectivity to allow movement
			Transitional flow: *Maintain functional flow components during spring and fall transitional periods.*	Maintain natural recession hydrograph during spring to promote productivity
				Maintain hydrologic response to fall freshets
		Protect, enhance, and restore geomorphic processes to healthy ranges	Sediment production and delivery: *Reduce fine sediment supply and suspended sediment concentrations*	Reduce fine sediment supply to channel
				Reduce suspended sediment concentrations
				Reduce open slope surface erosion and mass wasting
			Channel transport and storage: *Encourage dynamic sediment mobility and transport processes.*	Constant bed mobility, bed scour and sediment transport
				Transport sediment downstream at equilibrium with delivery rate
				Observe channel lateral migration over multiple years
				Reduced fine sediment deposition in channel
				Allow sediment deposition on floodplains
				Reduce riparian encroachment
				Increase/maintain substrate diversity
			Channel form and complexity: *Create and enhance complex channel forms (e.g., diversity in geomorphic units and substrate) that are the basis for high quality aquatic and riparian habitat.*	Increase the size, frequency, and topographic relief of bar/pool sequences
				Increase/maintain substrate diversity
				Increase channel sinuosity

	Goals	Sub-Goals	Objectives: action	Sub-Objectives
Landscapes (cont.)	Protect, enhance, and restore intrinsic physical watershed processes (e.g., hydrologic, geomorphic, and riparian) that create and maintain complex channel morphology and regulate habitat connectivity. (cont.)	Promote riparian corridor processes that support and sustain complex aquatic habitats	Riparian Zone Protection: *Limit activities that impact riparian vegetation and associated soils, geomorphology, and hydrology.*	Increase riparian buffer areas
				Allow terrestrial inputs (leaf matter and invertebrates) into channel
				Increase shading over river channel
				Increase recruitment of wood into channel
			Riparian Vegetation Dynamics: *Encourage geomorphic, sedimentological, and hydraulic processes that promote riparian seed dispersal, establishment, and growth in appropriate locations.*	Reduce riparian encroachment
				Maintain regular seed dispersal by riparian vegetation
				Maintain age diversity of riparian trees and vegetation
			Riparian Vegetation Diversity: *Encourage native riparian species diversity and structure that supports habitat and invertebrate food production.*	Maintain species diversity of riparian species
				Reduce non-native or nuisance riparian plants
				Maintain diversity of riparian phenology, leaf out/leaf drop timing
		Improve water quantity and quality	Water temperature: *Reduce water temperatures where the thermal regime has or will warm, and increase cold water refugia areas*	Maintain water temperatures in suitable range for focal species
				Restore thermal refugia and connectivity between them
			Nutrients and pollutants: *Minimize introduction of pollutants to the watershed from agricultural practices (e.g., herbicides, pesticides & fertilizers), roads (e.g., gas, diesel & oil) and return nutrient loads to natural levels to prevent overgrowth of cyanobacteria and toxic algae*	Minimize input of pesticides and anthropogenic toxins
				Maintain nutrient levels to support biological production but not overgrowth
				Restore turbidity to natural levels
			Dissolved oxygen: *Increase dissolved oxygen to healthy levels where appropriate to reduce lethal and sublethal effects on fish in egg, larval and juvenile life stages*	Maintain dissolved oxygen in water column to be suitable for focal species
				Maintain dissolved oxygen at high levels in interstitial spaces for fish egg and larval incubation

	Goals	Sub-Goals	Objectives: action	Sub-Objectives
Landscape (cont.)	Protect, enhance, and restore intrinsic physical watershed processes (e.g., hydrologic, geomorphic, and riparian) that create and maintain complex channel morphology and regulate habitat connectivity. (cont.)	Improve water quantity and quality (cont.)	Water volume (ground water and surface water): *Improve conditions to maintain groundwater and surface water in key locations*	Identify groundwater basins within the Eel River watershed that may be threatened by overextraction and/or require study to determine the interaction of groundwater and surface water flows (e.g., Covelo Valley, Willits Valley, Laytonville Valley, Lower Eel River at Ferndale, etc.)
				Identify key locations and landowners for summer flow augmentation

Table E-4. Tiered goals and objectives for conservation and watershed resiliency.

	Goals	Sub-Goals	Objectives	Sub-Objectives
Conservation	Protect the Eel River's natural resources through land conservation actions that promote habitat connectivity and resiliency	Increase amount of conserved and protected land	Conservation areas new and extended	Increase the size of existing protected areas, adding new protected areas and buffer areas to protect core habitat.
			Land acquisition and management by Government land management agencies, local conservancies, and Tribes	Seek a state or federal land designation for long-term Eel River watershed-wide conservation; this designation would serve as a mechanism for identifying priority acquisitions and acquiring private properties into public ownership and management. For example, elevate key riparian corridors to Eel River Greenways to be recommended as part of the Wildlife Corridors Conservation Act.
				Facilitate good management of existing Wild and Scenic River segments. Coordinate the creation of management plans for and communication between state and federal parties for WSR areas.
				Shift balance of property ownership toward more public ownership into land conservation designations; emphasize Eel River opportunities to contribute to 30x30 goals. Especially estuarine / salt marsh transition areas.

	Goals	Sub-Goals	Objectives	Sub-Objectives
Conservation (cont.)	Protect the Eel River's natural resources through land conservation actions that promote habitat connectivity and resiliency (cont.)	Increase amount of conserved and protected land (cont.)	Land acquisition and management by Government land management agencies, local conservancies, and Tribes (cont.)	Define and map existing Wild and Scenic Corridors to the standard 0.25-mile buffer in public lands. Coordinate with agencies to develop management for the standard buffer.
				Make recommendations to advance the management and extension of Wild and Scenic Rivers. Rank potential riparian resilience within the Wild and Scenic River (WSR) areas of the watershed to promote the protection of those areas. Work with management agencies to develop management plans for the WSR areas of the Eel.
		Establish and maintain connectivity and heterogeneity of conserved areas	Secure protection status for parcels that could bridge currently conserved or protected areas	Prioritize connectivity to existing protected areas. Link protected areas with riparian corridors or other natural areas where landscape impacts are low. (Collingham and Huntley 2000, Donald and Evens 2006, Synes et al. 2015).
				Establish working groups with local land management agencies to bridge resource management plans where rivers run through multiple agency holdings: NPS (Wild and Scenic Rivers management), BLM, USFS, RVIT
				Use strategic planning to manage an effective protected riparian corridor system or greenway: Create and protect upland forest corridors between wetlands and uplands.

	Goals	Sub-Goals	Objectives	Sub-Objectives
Conservation (cont.)	Protect the Eel River's natural resources through land conservation actions that promote habitat connectivity and resiliency (cont.)		Secure protection status for parcels that could bridge currently conserved or protected areas (cont).	Representation: Protect representative habitats across the landscape (Keeley et al. 2018). Include areas within urban boundaries, upland and lowland areas in the represented habitats. Identify green belts that can contribute connective pieces to a larger climate resilient network.
		Use climate refugia strategy for planning conservation areas	Apply climate refugia criteria to priority rankings for protected area recommendations	Prioritize reconnecting tributaries and mainstems to floodplains and protecting those connections.
			Define and map climate corridors	Focus on physical landscape level ecological processes that will support resilience to temperature change. For example, upland to lowland corridors that follow temperature and precipitation gradients will support species movement irrespective of climate impacts (Pearson and Dawson 2005).
			Riparian forest connection to landscape	In land adjacent to and or impacting riparian corridors, avoid conversion and advance durable protection measures, such as acquisition, voluntary easements, and less sprawl in potential development near forested areas. Retain forests to preserve carbon storage value, reduce sediment loads in rivers, cool air temperatures, and retain climate resilience.

	Goals	Sub-Goals	Objectives	Sub-Objectives
Conservation (cont.)	Protect the Eel River's natural resources through land conservation actions that promote habitat connectivity and resiliency (cont.)		Riparian connection to wetlands	Connect wetlands to riparian areas, prioritize those with dense vegetation values. Where vegetation values are low, prioritize revegetation, restoration, and connect to riparian corridors between existing protected areas and other core habitat.
			Climate mitigation strategy	Focus prioritizations to protect remnant and/or connecting parcels with low solar radiation, lower temperatures, and heat mitigating landscape features on interior sub-regions of the Eel, especially Tribe lands and Disadvantaged Community Areas (DAC) within the Middle Fork, North Fork, Van Duzen, and Upper Eel watersheds.

	Goals	Sub-Goals	Objectives	Sub-Objectives
Conservation (cont.)	Protect the Eel River's natural resources through land conservation actions that promote habitat connectivity and resiliency (cont.)	Use climate refugia strategy for planning conservation areas (cont.)	Improve fire protections	Strategize and connect with local forestry managers to support restoration action in vulnerable areas. Recommend revegetation where upland habitat connects to riparian corridors, incorporate USFS data from recently burned areas, updated vegetation maps post-fire impacts.
		Protect ecosystem services	Protect multi-benefit landscapes	which deliver multiple ecosystem services, are resilient and likely to persist under future climate conditions.
			Lesson impacts from drought land for revegetation, where those restoration actions could connect to riparian corridors.	Connect wetlands to riparian areas, prioritize those with dense vegetation values. Prioritize connective upland areas with low vegetation values or bare
			Protect and promote agriculture best management practices	Identify parcels of agriculture options for grazing management and tidal interface conservation easements

	Goals	Sub-Goals	Objectives	Sub-Objectives
Conservation (cont.)	Protect the Eel River's natural resources through land conservation actions that promote habitat connectivity and resiliency (cont.)	Protect ecosystem services (cont.)	Flood impact mitigation	The southern extent of the North Coast is more vulnerable to sea level rise than the north. We will partner with community and agency groups to recommend parcels for flood mitigation acquisition.
		Priority habitat data integration	Connect conservation values to restoration planning with analysis overlay	Crosswalk salmonid life-history needs by integrating other restoration plans and aquatic spatial data in the region (SHaRP, ERRCP [2024], Eel River Action Plan).
		Protect species diversity and persistence	Prioritize protection of high biodiversity areas, and areas with high terrestrial and aquatic species richness	Establish conservation targets for state listed species of concern and other important habitats by integrating available data into biodiversity metrics.
				Identify “critical salmonid refugia”
				Mitigate impacts of anadromous fish scarcity from Pikeminnow food web competition.
				Develop Early Detection and Rapid Response (EDRR) long term monitoring for invasive species at the sub region scale and eradicate invasive species.
		Develop regional partnerships	Form regional conservation partnerships	with Tribe land trusts, community land trusts, and other regional planning groups

Appendix F

Restoration and Conservation Actions

NOTE TO REVIEWERS:
This draft appendix is an in-process work product.

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Table F-1. Actions table for fish passage improvements.

Fish passage improvements: *Actions that improve aquatic habitat connectivity by improving volitional upstream and/or downstream movement of fish and aquatic species, particularly at man-made or otherwise anthropogenic barriers and obstacles such as road-stream crossings.*		
Actions	**Description**	**Channel archetype or location[1]**
Large dam modification or removal	Remove Scott Dam to allow fish access to historically available habitat in the Upper Eel River watershed	2 (cool mainstem), Coho (Mainstem Eel River, Middle Mainstem Eel River, Upper Mainstem Eel River)
	Remove or modify Cape Horn Dam to improve upstream and downstream fish passage by reducing potential for injury and delay	2 (cool mainstem), Coho (Mainstem Eel River, Middle Mainstem Eel River, Upper Mainstem Eel River)
Small dam modification or removal	Remove or improve passage at small dams	all
Road-stream crossing improvements	Upgrade culverts that impair fish passage, ideally with bridges or stream simulation designs	0 and 1.1, 1.2, 1.3
	Build bridges or install culverts to prevent driving over shallow riffles	all
Tide gate removal or modification	Remove or modify tide gates to improve fish passage opportunities	4 (estuary)
Tributary access improvements	Remove or modify sediment deposits at tributary confluences to improve juvenile and adult access into high quality tributary habitats and thermal refuges by excavate channels or install wood features that concentrate flow into channels	1.1, 1.2, 1.3 (cold and cool focus)
Mainstem passage at shallow riffles	Manage flow diversions at Potter Valley Project to support low flow fish passage through the mainstem Eel River and reduce potential for false attraction leading to partial migration.	2, 3

1 Locations include sub-watersheds associated with key threats to focal species from federal recovery plans. The focal species associated with the key threat is identified. Note that sub-watersheds referred to in recovery plans are slightly different than the seven primary sub-watersheds used in the Plan (Section 2.1).

Table F-2. Actions table for instream habitat enhancements.

Instream habitat restoration: *Actions that increase or improve physical habitat conditions within the active stream channel and adjacent floodplain to support greater abundance and/or life history diversity for focal fish species.*		
Actions	**Description**	**Channel archetype or location**
Large wood addition	Includes single and multiple large wood placements and engineered logjams. Addition of large wood to increase habitat complexity and cover for fish in channel, and promote local bed scour and sediment sorting, and provide high flow velocity refuge.	1.1, 1.2
Large rock/channel roughening additions	Addition of large boulders or other features to increase in-channel habitat complexity and cover for fish, promote local bed scour and sediment sorting. Can be combined with large wood structures.	1.1, 1.2
Active channel reconfiguration	Mechanical/active reconfiguration of reaches to restore riffle-pool sequences, increase channel sinuosity, create side channels, increase pool frequency and depth, and other habitat complexity elements.	1.1, 1.2, 2 Steelhead (South Fork Eel River,
Beaver dams analogs	Addition of beaver dam analogs to increase habitat complexity, flow retention, sediment storage, and create low-velocity habitats to support rearing and high flow refuge.	1.1, 1.2
Bridge/overpass modifications	Modify bridges and road overpasses to reduce effects on channel form and process	all
Bank protection modification or removal	Modify or remove bank protection (e.g., riprap) to allow channel migration and formation of under-cut banks. Frequently preformed in combination with land conservation action to allow for channel expansion.	all

Table F-3. Actions table for off-channel habitat restoration and connectivity.

Off-channel habitat restoration and connectivity: *Actions that increase or improve physical habitat conditions outside the active stream channel but within the riparian/floodplain corridor that have at least seasonal connectivity (e.g., during high flow periods) to support greater abundance and/or life history diversity.*

Actions	Description	Channel archetype or location
Floodplain reconnection	Mechanical reconfiguration to improve hydraulic connection between active channel and floodplain, particularly in reaches where channel incision has occurred and stream is disconnected from floodplain and/or side channels	1.1, 1.2, 2,3
Bank protection modification or removal	Removal or modification of levees or other bank protection (e.g., riprap) to allow channel migration and floodplain reconnection. Frequently done in combination with land conservation action to allow for channel expansion.	all
High-flow side channel construction or reconnection	Construct complex high-flow side-channel to increase habitat complexity and provide high flow velocity refuge	1.1, 2, 3
Off-channel pond construction or reconnection	Construct off-channel pond or alcove to provide high flow refuge habitat	1.1, 2, 3
Focused restoration planning in rare, large valleys where off-channel habitat restoration is expected to have greater opportunity and value	Need to highlight need for focused restoration planning in rare, large valleys where off-channel habitat restoration is expected to have greater opportunity and value	(Round Valley, Little Lake Valley, Laytonville/Ten Mile Valley)

Table F-4. Actions table for estuary habitat restoration.

Estuary Habitat Restoration: *Actions that increase or improve physical habitat conditions or habitat connectivity within the estuary, floodplain, and stream-estuary ecotone*		
Actions	**Description**	**Channel archetype or location**
Levee set-back or removal	Removal or modification of levees or other bank protection to allow tidal channels to form and floodplain areas to reconnect	4 (estuary)
Tide gate upgrade or removal	Restore tidal prism and provide fish passage	4 (estuary)
Re-establish historical slough channels	Reconnect and restore historical slough channels	4 (estuary)
Reconnect freshwater tributaries to estuary	Restore connectivity between estuary and tributaries that have been disconnected	4 (estuary)
Install livestock fences	Install exclusion fencing to protect channels and banks from trampling	4 (estuary)

Table F-5. Actions table for Instream flow protection and enhancement.

Instream flow protection and enhancement: *Actions that increase, improve, or protect water supply and aquifers or conditions that maintain surface and groundwater that contribute to supporting instream flows for fish and other aquatic species and the ecosystems they depend on (e.g., riparian corridor ecosystem)*		
Actions	**Description**	**Channel archetype or location**
Regulate/reduce summer water diversions	Reduce water diversions and groundwater extraction/pumping during summer that reduces summer flow volume	0, 1, 2, Coho (South Fork Eel River); Chinook (South Fork Eel River, lower Mainstem Eel River, Upper Eel River, Van Duzen River) Steelhead (South Fork Eel River,
Establish diversion guidelines/rules for Potter Valley Project that protect fish and ecosystem processes	PVP water management and diversions can affect fish passage and movement as well as fish life history, growth, and production. Water diversions should be protective of these considerations and other ecosystem processes.	2 (cool mainstem)
Develop off-channel water storage programs	Encourage and facilitate winter high-flow diversions that store water in stable (lined) ponds for summer flow augmentation	0, 1, 2
Beaver dam analogs	Install beaver dam analogs to provide flow retention, groundwater recharge, and locally increase the water table.	1.1, 1.2, 2
Beaver reintroduction	Reintroduce beaver to provide flow retention, groundwater recharge, and locally increase the water table	1.1, 1.2, 2
Stream flow gaging	Monitor streamflow at critical points in the watershed to establish and frequently evaluate instream flow needs	2

Table F-6. Actions table for Water Quality Improvement.

Water quality improvement (including water temperature): *Actions that improve water quality conditions for fish and other aquatic species and support the ecosystem on which they depend including water temperature, water chemistry, fine sediment, and pollution.*		
Actions	**Description**	**Channel archetype or location**
Identify, protect, enhance, and provide access to thermal refugia	Thermal refugia may include lower reaches of cool tributaries and their coldwater plumes in adjacent mainstems, thermally-stratified deep pools, wetted reaches below dry/sub-surface reaches, estuarine/coastal oriented habitats, headwater streams.	1.1-W, 1.2-W, 2-W, 3, 4
Reduce summer water temperature in key rearing habitats	Identify locations where summer water temperatures are near the threshold for suitability and develop strategies for improvement	1, 2
Reduce nutrient loading	Identify and reduce point- and non-point source nutrients where high nutrient supply determined to be an issue	all
Reduce fine sediment loading (also see upslope sediment control)	Reduce fine sediment supply to watercourses and streams from streambank and upslope sources	1, 2, 3
Riparian re-vegetation	Improve riparian vegetation conditions	0, 1, 2

Table F-7. Actions table for Riparian and wetland habitat restoration.

Riparian and wetland habitat restoration: *Actions that increase, improve, or protect riparian and wetland habitat conditions that influence channel form and geomorphic processes (e.g., large wood supply), aquatic habitat conditions (e.g., stream shading, water quality), and ecology (e.g., allochthonous inputs).*

Actions	Description	Channel archetype or location
Riparian vegetation management	Improve riparian Habitat function and composition through thinning and planting. Plant riparian trees and shrubs where historic clearing or large fires have impacted riparian cover/shade	Chinook (Larabee Creek)
Riparian fencing or livestock management	Protect riparian areas from livestock, particularly where summer water temperatures are high and shade has been reduced, and where bank stability and sedimentation are issues of concern.	all
Riparian buffers and protection	Protect riparian habitat within stream meander belt/riparian corridor to allow natural channel process and local wood supply	0, 1, 2, 3
Wetland habitat protection and restoration	Protect and/or restore wetland areas within the riparian corridor to provide seasonal habitat and/or contribute	all

Table F-8. Actions table for streambank and upslope sediment control/management.

Streambank and Upslope sediment control/management: *Actions that decrease sediment delivery rates to streams particularly increased sediment supply caused by man-made infrastructure (e.g., roads), land management activities (e.g., timber harvest), or other anthropogenic disturbance (recreation, increased wildfire activity).*

Actions	Description	Channel archetype or location
Reduce sediment delivery from roads	Perform road maintenance where sediment issues have been identified	Coho (North Fork Eel, South Fork Eel, Middle Fork Eel, Middle Mainstem Eel River, Upper Mainstem Eel River); Chinook (South Fork Eel River, lower Mainstem Eel River, Upper Eel River, Van Duzen River) Steelhead (South Fork Eel River,
	Remove or replace undersized and failing culverts	
	Decommission roads that are no longer needed	
Reduce sediment delivery from severely eroding banks	Install features to prevent mass wasting (e.g., willow walls)	0, 1, 2, 3
	Line ponds to prevent mass wasting	0, 1, 2
Wildfire management	Fire management to reduce fuels. Support cool, controlled burning over fast, uncontrolled, destructive burning	Coho (North Fork Eel River), Chinook (Upper Eel River)
Vegetation management	Manage upslope vegetation to avoid young, dense forests that are prone to high severity wildfire	Coho (North Fork Eel River), Chinook (Upper Eel River)

Table F-9. Actions table for invasive species and disease management.

Invasive species and disease management: *Actions that reduce the impact of invasive species on focal fish species, particularly predation by non-native fish (e.g., Sacramento pikeminnow).*		
Actions	**Description**	**Channel archetype or location**
Removal, control/suppression, and/or monitoring of non-native fishes	Reduce abundance of Sacramento pikeminnow	Coho (Mainstem Eel River), Chinook (Upper Eel River, Van Duzen River) Steelhead (South Fork Eel River)
	Physical removal (e.g., through targeted angling, e-fishing, weirs) or genetic extinction (e.g., Trojan Y)	1, 2, 3
Monitoring/prevention/early detection of aquatic invasive species	Invasive aquatic species including fish and other taxa. Smallmouth bass is a significant concern because of their potential to establish. Mussels and snails are a concern because of their potential to change ecological processes and food web dynamics.	all
Removal, management, and/or monitoring of non-native terrestrial wildlife	Invasive terrestrial species including wild boar and feral pig are a concern because of their potential to disturb riparian vegetation and soil.	0, 1, 2
Removal, management, and/or monitoring of invasive plant species within riparian corridor	Invasive terrestrial species including Arundo etc. are a concern because of their potential to displace native species.	all
Fish disease monitoring	A monitoring program is needed to understand / monitor prevalence of fish diseases in the Eel River (similar to Klamath)	2, 3

Table F-10. Actions table for active species management.

Active species management: *Actions that improve habitat conditions or productivity of focal fish species through active species management (e.g., beaver re-introductions; hatchery or hatch box program).*

Actions	Description	Channel archetype or location
Beaver reintroduction, management, and/or relocation	Beaver dams and activities can increase habitat complexity, improve growth and survival, regulate flow and sediment, and increase water table.	1.1
Develop conservation hatchery or hatch box program	Enhance production of focal species through conservation hatchery or hatch box program.	1.1-cold, 1.2 cold, 2-cool

Table F-11. Actions table for land conservation.

Land conservation: *Actions that protect or conserve lands with unique, important, and/or intact habitats to maintain or improve river corridor habitat, preserve natural processes, and/or improve habitat connectivity over 10s to 100s year time scale.*

Actions	Description	Channel archetype or location
Promote and expand conservation easements	Protect and connect high-quality habitats	all
Establish streamside protected areas to encourage riparian growth in heavily populated/visited areas		all
Expand Wild and Scenic River designation and protections	Coordinate management among agencies—NPS, State, BLM, USFS	
	Write management plan for areas outside of Federal management	

Table F-12. Actions table other potential strategies.

Other potential strategies		
Actions	**Description**	**Channel archetype or location**
Community outreach and watershed education	Continue Eel River Forum meetings	n/a
	Support youth education programs	n/a
	Support community science participation	n/a
Improve biotic conditions to increase food supply and juvenile growth	Supplement nutrients through fish carcass/egg additions or other strategies	1
Regulatory	Wild and Scenic River designation	See Plan section 1.3.5.
	Fishing regulations and fisheries management	2, 3, Steelhead (South Fork Eel River)